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ABSTRACT

This manual provides information needed to meet specific standards for certification as a pesticide applicator. Each of the eight chapters deals with a different aspect of pesticide use. Chapter one discusses the problems of use as it relates to safety of humans and the environment. Chapter two is concerned with the identification and diagnosis of insects and disease while the third chapter discusses equipment types and their utilization. The remaining chapters deal with forests and forest crops; forest weeds; forest insects, nematodes and diseases; and bird and mammal pests. (CS)

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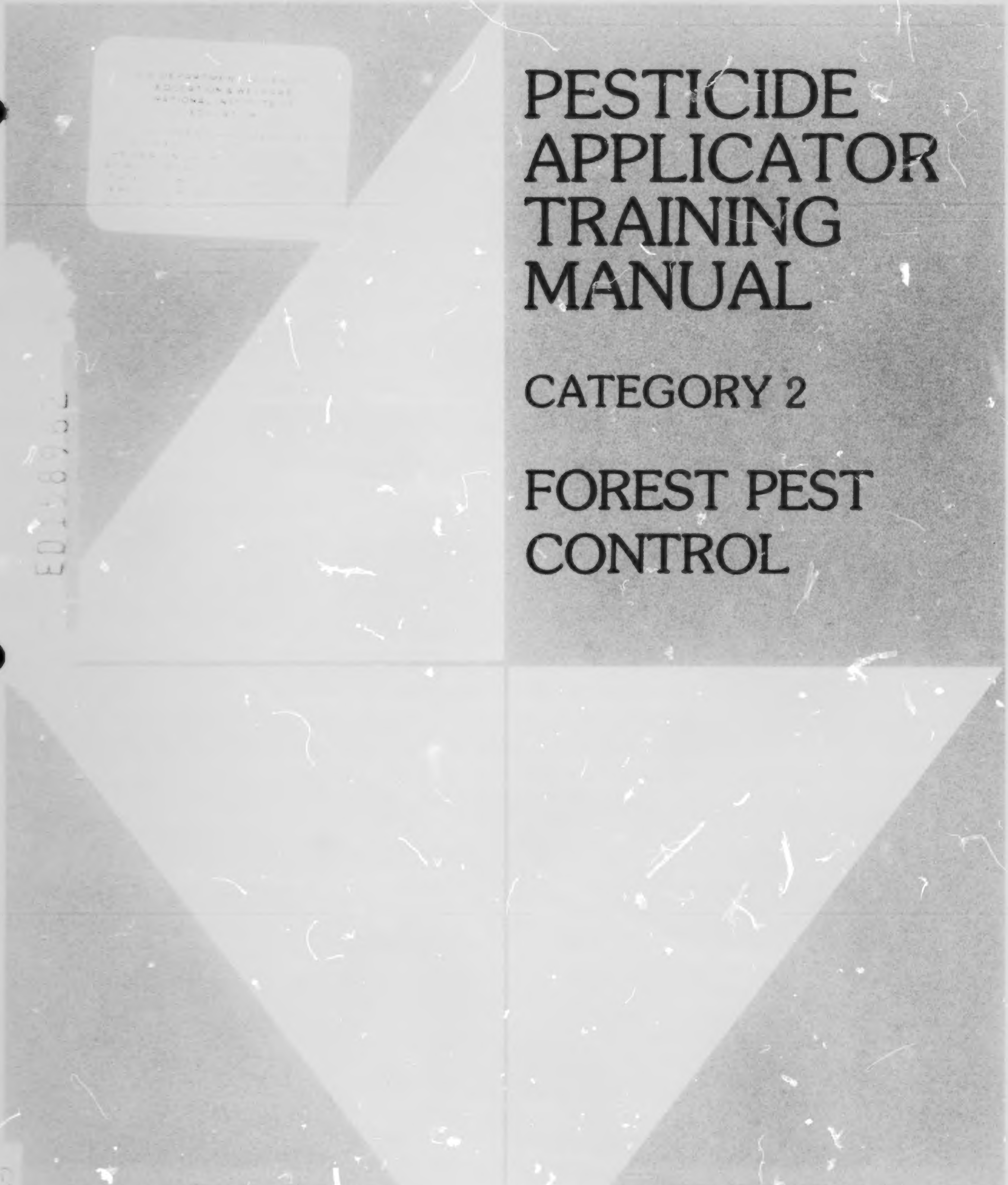

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PESTICIDE APPLICATOR TRAINING MANUAL

CATEGORY 2

FOREST PEST CONTROL

INSTRUCTIONS FOR USING THIS TRAINING MANUAL

This training manual is intended to provide you with the information you will need to meet the standards of the U. S. Environmental Protection Agency for commercial certification as a pesticide applicator in the category Forest Pest Control and to prepare you to take an examination given by the pesticide regulatory agency based on this manual. It is not intended that this manual or training will provide you with all the information that you need for effective pest control. Up-to-date information regarding recommended materials and methods should be obtained from your Cooperative Extension office, your state extension publications, and the label.

The manual is designed for use as a self-study manual by individuals, or it may be used in conjunction with other training materials at training schools. Your core manual (either the Northeast or EPA-USDA core training manual) is the basic information manual for all pesticide applicators. This manual begins where the core manual left off. Refer back to your core manual as necessary.

This manual was developed to be used in an open book exam since it contains resource information that is not intended for memorization. It will require careful study so that you are sufficiently familiar with its contents that needed information can be quickly found and used within the period allowed for examination.

You should place this manual in the same binder with your Northeast Core Manual or with the core manual you used for certification at the core level to qualify you for category certification.

PESTICIDE APPLICATOR TRAINING MANUAL

CATEGORY 2

FOREST PEST CONTROL

A Training Program for the Certification
of Commercial Pesticide Applicators

Cooperative Extension
Chemicals-Pesticides Program
New York State College of Agriculture and Life Sciences
at
Cornell University, Ithaca, New York
January 1977

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INTRODUCTION

You have completed the core training of pesticide certification and now are about to start additional training for your commercial certification. This manual will cover information in the following commercial categories:

a) Agricultural (plant)
b) Forestry
c) Ornamentals and Turf

Forest pests are defined as pests occurring in forests, forest nurseries, and forest seed producing areas.

You will be responsible for the general information that appears in Chapters I, II, and III, along with the specific information that pertains to your category training, but not for all the information presented. For example, if you are a forest nursery manager, you would not be expected to know how to calibrate orchard airblast equipment.

The purpose of this manual is to:

-- provide federal minimum category standards for certification
-- provide identity to some common problems in the use of pesticides
-- provide identity to some common pests
-- provide methods of calibration, maintenance and operations of equipment used in the application of pesticides in agriculture

This manual focuses on principles which apply to your operations and which will enable you to improve your competency to use pesticides.

Standards for Certification

The Environmental Protection Agency has set minimum standards for certification of pesticide applicators. Among these standards is a section relating to your operations as a commercial applicator.

The specific standards from the Federal Register for this category of commercial applicators are as follows:

> "Applicators shall demonstrate practical knowledge of types of forests, forest nurseries, and seed production in their State and the pests involved. They should possess practical knowledge of the cyclic occurrence of certain pests and

specific population dynamics as a basis for programming pesticide applications. A practical knowledge is required of the relative biotic agents and their vulnerability to the pesticides to be applied. Because forest stands may be large and frequently include natural aquatic habitats and harbor wildlife, the consequences of pesticide use may be difficult to assess. The applicator must therefore demonstrate practical knowledge of control methods which will minimize the possibility of secondary problems such as unintended effects on wildlife. Proper use of specialized equipment must be demonstrated, especially as it may relate to meteorological factors and adjacent land use."

Responsibility for Certification

It is the Environmental Protection Agency's responsibility to see that minimum standards are met. A lead agency is designated in each state that is responsible to EPA for certification training and enforcement. The Department of Environmental Conservation is the lead agency for New York State. Within the agency the Bureau of Pesticides has all regulatory responsibilities dealing with pesticides, including preparing and giving the examinations for certification and enforcing the requirements.

Cooperative Extension is responsible for training pesticide applicators in preparation for certification. The core level of training for both private and commercial applicators is offered in individual counties through the local Cooperative Extension field staff. Category training is offered by teams of specialists (mainly from Cornell), usually on a regional basis. All examinations are administered by a representative of DEC.

Forest Types, Crops and Pests

Applicators must demonstrate practical knowledge of forest types, forest crops, and the pests on which they may be using restricted use pesticides.

Your full and adequate knowledge of crops and pests for which you provide service is basic to performance of your work. You must:

- accurately identify the pests
- select the correct registered pesticides
- determine the necessity of chemical control

-- apply the most effective and efficient control measures

With this knowledge, your ability to provide safe and effective service will be maximized.

Concern for Others

Practical knowledge is required to recognize:

- -- soil and water problems -- leaching, residues, erosion, etc.
- -- reentry intervals
- -- phytotoxicity and potential for environmental contamination
- -- nontarget injury
- -- community problems (such as "in-line" housing, streams, ponds, or lakes, school grounds, etc.) resulting from the use of restricted use pesticides in forested areas.

Recognition of potential contamination of water by your application of pesticides is essential.

Reentry intervals are established for the safety of your workers and those of your customer. You are responsible for making sure that your customer is completely informed about these intervals.

Bad habits and sloppy practices can result in environmental contamination and can be avoided or reduced by careful supervision and strict attention to approved methods and directions for use of pesticides. Careless habits resulting in misuse, littering the landscape and contaminating the environment are not only prohibited by law, but contribute to bad public relations.

Areas adjacent to the target areas may receive pesticide drift. This can result in harmful residues on food or feed crops, or in the case of herbicides, may result in plant injury.

Your concern for the environment, including people who live, play or work near your operations, is vital to your future.

I. PROBLEMS WITH PESTICIDE USE

Your core manual deals mostly with the acute hazards of pesticides to man and other warm blooded animals that are associated with handling of highly toxic pesticides. As a commercial applicator you are daily exposed to many pesticides ranging from low to high toxicity. You must consider their total effect on yourself, and such possible side effects as phytotoxicity, bee toxicity, drift damage, reentry, residues, tolerances, etc. Your health and repeat business depends on your knowledge and care in application.

Hazards to the Applicator, Worker and Consumer

Dermal Toxicity to the Applicator

You must not swallow, touch, or inhale pesticides. Your greatest hazard from pesticides is from skin contact which results in absorption through the skin. According to a survey in a leading agricultural state, absorption through the skin was responsible for over 80% of the cases of poisoning from agricultural and industrial use of agricultural chemicals. This can result from a splash, spill, or drift when you and/or your help are mixing or applying the chemical, or from contact with a pesticide "deposit" or "residue" after it has been applied.

The hazard of skin absorption is increased by cuts, abrasions, scratches, scuffs, or other damage to the skin. However, absorption can occur rapidly even through healthy skin. Absorption is high and rapid through the scrotum, arm pit, ear canal, forehead and scalp. It is lower and slower in the palm of the hand, or ball of the foot. However, even in these lower absorption areas, penetration can be great and vary from material to material. Carbaryl (Sevin) for example, is thought of as a relatively safe material, but is absorbed through the skin of the forearm about seven times more rapidly than malathion or parathion. Whether highly toxic or relatively safe, any pesticide spilled or splashed on the skin should be washed off immediately. Studies show that pesticides can be absorbed within a few minutes. Waiting until a job is done before washing may be too late! Wash by rubbing the hands together or with a piece of cloth using detergent or soap. Do not scrub with a brush since the outer protective layer of the skin may be scratched enough to allow more rapid absorption of any pesticide which is not removed. Hands should be protected with gloves when working on spray machinery.

Eyes

Eyes are particularly sensitive to harm by pesticides and should be protected with goggles or a face shield. If pesticide is splashed into the eye, immediately wash it with a gentle stream of clean running water while holding the eyelid open. A few seconds delay greatly increases the extent of injury. Large amounts of water should be used and continued for 15 minutes or more. Do not use chemicals or drugs in wash water. They may increase the injury. Convenient plastic eye wash bottles and holders are now available. These useful bottles can be purchased from chemical laboratory suppliers and are called "eye wash stations."

Lungs

Most applicators do not feel that inhalation of pesticides is a serious hazard. It is next in importance to skin contact as a cause of agricultural accidents. Because the lungs have such a large and highly absorptive surface area, even small amounts of pesticide are hazardous because they are almost completely absorbed. Vapors and extremely fine particles, 10 microns or smaller, are a particular hazard. Field tests in fruit orchards with airblast sprayers using eight times the normal dilute concentration have shown that the respiratory hazard is about three times greater than when operating with conventional dilute sprayers. Respirators should be worn as indicated on the pesticide label and whenever else that you think such protection is desirable. Occasional use of most moderately toxic pesticides does not usually require use of a respirator. Daily use of these pesticides, however, greatly increases your exposure and may necessitate use of a respirator. It is also wise to wear a respirator when using moderately toxic pesticides such as malathion during the same day or days that you are using highly toxic pesticides of the same family.

Respirators and Gas Masks for Pesticides

All respirators intended for use with pesticides must be approved jointly by the Mining Enforcement and Safety Administration (MESA) and the National Institute of Occupational Safety and Health (NIOSH). Approval numbers beginning with the letters TC are assigned to all respirators approved by the new agency. This number must be on the box containing the facepiece. Cartridges and filters approved for pesticides are necessary and must have the TC number affixed to them plus the part number of the replacement part. Chemical cartridge respirators approved for pesticides will have the code number 23C following the letters TC and gas masks will have the number 14G following TC. Respirators having numbers other than TC numbers (i.e., BM numbers) are no longer approved unless they can be upgraded to meet requirements through the use of appropriate cartridges and filters.

As of April 1, 1976, it is our understanding that the following respirators are approved for pesticide use under the new standards:

Standard Chemical Cartridge Respirators

-- MSA number 459520 respirator with 459519 cartridge. Approval number TC-23C-45. Mine Safety Appliances Co.

-- Willson AGRI-TOX-2 respirator. 1200 series respirator with R21 Chemical Cartridges, R15 filters and R683 filter retainers. Approval Number TC-23C-54. Willson Products Division, ESB, Inc.

-- Welsh 7549 respirator with 7500-21 cartridges and 7500-23 filters. Approval number TC-23C-74. Welsh, A Textron Co.

-- MSA 448848 respirator with 448847 cartridges. Approval number TC-23C-79. Mine Safety Appliances Co.

-- AO number R5058 or R6058 respirator with R58 cartridge. Approval number TC-23C-106. Safety Products Division, American Optical Corp.

-- Pulmosan number C-241 respirator with TC-23C-81 organic vapor cartridge and C-241-7 filter. Approval number TC-23C-110. Pulmosan Safety Equipment Corp.

Powered Air Purifying Respirators

-- 3MW262 and W263 powered air purifying respirators with W2114 cartridge and W2031 filter. Approval number TC-23C-78. 3M Co.

Gas Masks

-- MSA Clearview or Ultraview Chin Style Gas Mask Systems with Pesticide Approved Canister (Numbers 448983, 448984, 448985, and 448986). Canister alone is 448972. Approval number TC-14G-86. Mine Safety Appliances Co.

Reentry Into Treated Fields - (Don't confuse with number of days from last spray to harvest).

These standards were established in 1974, apply particularly to agricultural uses and were established to protect workers. Although you as the commercial applicator may feel that you are not directly involved, there are some rules you must follow. These are:

1. No unprotected person may be in the field you are treating with any pesticide!
2. No pesticide application is to be permitted that will expose any person to pesticides, either directly, or through drift, excepting those involved in the application, who should be wearing protective clothing as required.
3. The label restrictions and directions must be followed.

Those pesticides presently (October 1975) restricted and requiring workers to wear protective clothing within the 24- or 48-hour reentry period after treatment are:

24 hours	48 hours	
Guthion	ethyl parathion	carbophenothion
phosalone	methyl parathion	Meta-Systox-R
EPN	demeton	Bidrin
ethion	Azodrin	endrin

It is your responsibility to keep abreast of changes in these pesticide restrictions.

Although not absolutely necessary any time that you apply one of the above materials, it is recommended that you notify your client to avoid misunderstanding, poor public relations and possible litigation. Tell him the name of the material, time of application and the required reentry period during which protective clothing must be worn so that he may inform his employees accordingly. If workers must enter fields prior to expiration of the required interval, growers are obligated to notify workers of the date of treatment and furnish them with protective clothing.

Fields treated with pesticides other than those listed above may be reentered without protective clothing after the spray has dried or the dust has settled. New labels will indicate the necessary reentry information, old labels will not (refer to list above).

State regulatory agencies may impose and enforce standards for workers that are more restrictive than those specified. Check your state regulations.

Days to Harvest Interval

Don't confuse days-to-harvest intervals with reentry intervals. Days-to-harvest is the time that must pass between pesticide application and crop harvest to protect the consumer by allowing the pesticide residue to fall to or below a specific tolerance level. The same pesticide will have different intervals for different crops, based on dosages necessary to control pests, different surfaces treated, whether edible parts are treated, stripping or washing outer leaves, etc. Check the harvest interval before an application is made.

Hazards to the Crop

Probably the greatest hazard to the crop is an adverse reaction to the chemical applied. "Phytotoxicity" or chemical injury results in stunting, burning, deforming, or death of the crop.

Phytotoxicity or Chemical Injury

Pesticide injury to plants may be the result of direct application to the plant; spray, dust, or vapor drift onto the plant; runoff from a treated field or persistent soil residues which can damage a sensitive crop planted in an area previously treated. Injury to the plant may appear as dead, burned, or scorched spots on or at the tips of leaves; russeting of fruit; misshapen fruit, leaves, or plants; off-color; stunting; delayed development; poor germination; or complete death of the plant. Unfortunately, these signs of chemical spray injury often do not appear until several days after application. When they do appear, they are not always clearly understood and they are often confused with other problems such as: signs or symptoms of a disease; insect injury; uneven application of fertilizer; nutrient deficiency or excess; poor drainage or poor soil; frost injury; hail, drying winds; hot weather; shading; poor lighting; or air pollution. Generally, however, there are clues which help you solve the problem. Some are: location of injured plants; location of injured areas on the plant or fruit; nature of the injury itself; lack of signs of other causes of the injury such as ooze or fungus growing from the injured spot; weather records; cropping history; location in relation to highways, industrial plants, cities; etc. Sometimes it may be necessary to call upon experienced people to help determine the correct answer. Generally, the injured areas are sharply defined between injured and healthy tissue. Color of the injured area is usually uniform. Spots may be evenly distributed or confined to a spot where a drop of spray accumulated on the low area of the leaf or fruit.

The likelihood of plant injury resulting from the use of a pesticide varies with the chemical, the formulation used, the concentration, the method of application, the growing conditions and the stage or condition of the plant. Desiccants, defoliants and herbicides are effective because of their ability to kill foliage and destroy plants. They are, therefore, particularly hazardous through drift to sensitive plants. Organophosphates, carbamates, and oils are more likely to cause injury when drying conditions are poor. Chlorinated hydrocarbons, on the other hand, are more apt to be injurious in hot, dry weather. Emulsifiable concentrates, because of the solvents in them, are more likely to cause injury than wettable powders since they allow the chemical to come into direct contact with the plant tissue by dissolving the waxy protective layer on the leaves. Mixtures of pesticides, especially soluble or emulsifiable formulations, are more likely to cause injury in sensitive situations than materials applied individually. Similarly, applications with high pressures may cause injury when lower pressures would not. Injury may appear at the end of rows or near the edges of treated fields because of slower travel rates, turning and stops. Phytotoxicity may result under some of these conditions even when recommendations are followed. Severe injury, however, is unlikely and is a sign of other problems.

Growing conditions can also influence plant sensitivity to chemical injury. Weak plants such as those in shallow soils, wet spots, etc., are more susceptible to injury than are healthy plants. Young, tender, fast growing plants with large areas of new growth tend also to be more susceptible to injury. Differences in the sensitivity of varieties is not uncommon.

Hazards to Non-target Areas or Organisms

These hazards are the result of a pesticide hitting the wrong target within the crop, drifting away from the crop, or being mishandled.

Hazard to Bees (See inside of back cover)

Honey bees and wild bees are necessary for pollination of many crops. Many pesticides are highly toxic to honey bees, wild bees and other beneficial insects. You can reduce bee poisoning if you follow these suggestions:

- Do not apply pesticides that are toxic to bees to crops that are in bloom, including cover and adjoining crops.
- Select pesticides that will be least harmful to bees.
- Try to choose the least harmful formulations. Dusts are more hazardous than sprays. Emulsifiable concentrates seem to have less residual toxicity than wettable powders. Granular formulations have the lowest hazard to bees.
- Try to time pesticide applications so that the hazard to bees will be as low as possible. Evening applications are generally less hazardous than early morning. Both are safer than mid-day applications. For example, short residual pesticides might be applied at night between sunset and sunrise to minimize injury to foraging bees in the field needing treatment. Because corn and milo stop shedding pollen about noon, and bees collect the pollen, short residual pesticides should be applied in mid-afternoon or evening to protect the bees.
- Do not treat near hives and try to avoid pesticide drift over or onto hives. Coarse sprays will help reduce drift. If a hazardous pesticide must be applied near hives, contact the beekeeper ahead of time and ask him to remove his bees.
- When a cover crop is in bloom, as in an adjoining field, the grower may be able to greatly reduce the hazard by mowing it before treating.

Drift

Pesticides are not pollutants as long as they stay on target. Drift of pesticides away from the target is probably the most important and costly problem facing most commercial applicators. Drift is important because of possible injury to non-target plants and animals, and illegal residues that may make neighboring food crops unsalable. Poor public relations with those living around the target area may cause the loss of use of effective pesticides because of their side effects, and may result in loss of certification because of misuse.

Drift is costly because of: possible lawsuits resulting from off-target injury or unsalable crops; local public reactions that may prevent a potential program from being developed and carried out, and most important to commercial applicators, the loss of working time because of conditions that will cause harmful drift. The control of drift is your responsibility!

You, as a commercial applicator, have legal liabilities. You can be fined up to $25,000 and sentenced to one year in prison for gross misuse. You may also face loss or suspension of certification. Additionally, smaller misuses and penalties can seriously hurt your reputation.

Almost any pesticide application will result in some drift, which can be serious or relatively harmless. Ideally you should work when there is no wind. Practically speaking this is not often possible. But, if there are sensitive areas downwind, i.e., homes, pastures, water, sensitive crops, etc., you can often arrange your schedule to treat the sensitive areas when there is little or no wind, usually in early morning or evening. Less sensitive areas can be treated when the weather conditions are not as good. The risk is less if the crop downwind calls for the same pesticide as the target, or if the area to be treated is located away from houses, streams, or other such areas. You can sometimes influence your clients to plant high risk crops in low risk areas. You simply must have the good judgement to stop treatments when conditions are too poor. Such action may save you money and your reputation.

The machinery you use will influence your drift problems. If you use granular applicators, generally you will not have a great drift problem (although broadcast application in high wind will result in a poor application pattern). Sprayers cause more drift than granular equipment and the amount of drift varies widely according to the type of sprayer. Power dusters are no longer widely used, one reason being the excessive drift that results from their use. You can reduce drift by setting your equipment correctly for a particular job. Remember:

-- There is more chance for drift with airblast sprayers than with boom sprayers.
-- There is more chance for drift with high pressure sprayers than with low pressure sprayers.
-- Low volume concentrates are more apt to cause drift damage than high volume dilute mixtures.
-- ULV sprayers present the greatest hazard for drift because the droplets are necessarily fine in order to get coverage.
-- Smaller droplets drift further than larger droplets.
-- The higher the boom or nozzle from the crop, the more chance for wind effect and drift.

If you keep these principles in mind you can operate your equipment to minimize drift.

When using airblast equipment, follow these practices to reduce drift:

-- Direct nozzles with the airblast to give coarsest droplets that will be effective.
-- Use lower pump pressures to give larger droplets.
-- Determine the effective swath width and calibrate. Plan the spraying pattern of the field accordingly.
-- Operate in little or no wind. Not only will wind cause drift, but it will distort the swath pattern.
-- Choose a time to operate when drift is away from sensitive areas.
-- When spraying near sensitive areas be sure the airblast is directed away from them.

When using boom equipment, follow these practices to reduce drift:

-- Use lower pressures and spray discs with larger openings to increase droplet size. Using higher total volume per acre will allow larger droplets without reducing coverage.
-- Choose the best type of nozzle. Hollow cone nozzles produce more "fine" droplets than flat fan nozzles. Newly developed nozzles are available that collect these "fines" together into larger droplets while they are still within the nozzle, thus reducing drift (fines can drift long distances).

-- Keep booms mounted as low as possible to reduce wind effects. Use closer nozzle spacing and wider fan angles.
-- Position boom to give larger droplets if ground speed is high (10 - 15 mph). Tilting the boom forward results in finer droplets; tilting backward gives larger droplets.
-- Be sure sprayer is properly calibrated -- don't overdose.

Your choice of chemical and formulation has a significant effect on drift. Granules do not ordinarily drift very much because they are relatively large and uniform in size, although toxic dust can escape from some formulations. Dusts can drift badly because the particles vary widely in size and include a high percentage of small lightweight particles.

Many sprayers produce vast numbers of "fines". You can reduce fines by physical means - lowering pressure, using larger nozzles, etc. Materials called adjuvants that act as thickeners or foaming agents can be added to the spray tank. These materials increase the number of larger droplets and decrease the number of fine droplets. Some are simply added to the tank and others are pumped through special mixing pumps and/or nozzles. Sometimes the spray is thickened and other times it is made into a foam. All such adjuvants reduce drift by reducing the number of fine droplets, but no method makes a spray drift-proof.

In addition to actual physical drift of droplets, certain materials vaporize, thus producing fumes which may cause damage for long distances downwind. These materials are "volatile" and include esters of 2,4-D, 2,4,5-T and other phenoxy compounds, dinitros, and some carbamate herbicides. High-volatile forms can vaporize rapidly at 65 degrees F and high temperatures of 80 to 90 degrees accelerate vaporization of the high-volatile formulations and even vaporize low volatile esters of phenoxy type herbicides. Amine formulations are usually considered non-volatile although extremely sensitive plants can sometimes be damaged. Obviously, you would choose an amine formulation or low volatile-esters rather than a high volatile ester in a sensitive situation. Spray on the coolest part of the day. Avoid high temperatures and low humidity.

Contamination

Pesticides need careful attention even when they are intentionally placed on a target, placed in storage, located in a sprayer or on a truck. They often appear where they were not placed or wanted and thus cause problems. Such places include our general surroundings (air, soil and water) and also our more intimate surroundings (equipment, storage, clothing, shoes) and even within our bodies. Some pesticide residue is purposeful, as when spraying a crop or applying a preemergence herbicide. Some is expected, like the residue in a sprayer; but some is unwanted and may be an inconvenience, contaminant, or hazard. Since your contact with pesticides is greater than that of the average person, you must be particularly careful not to over-expose yourself.

Every pesticide application that is made in the field will result in some air and soil contamination, which may be followed by contamination of water. The extent of this contamination will depend on several choices that you make. Your first goal is to keep the pesticide within the target area. (During some spraying operations more than 50% of the pesticide fails to reach the target and cannot be accounted for, except that it escapes into the environment). Secondly, you must consider drift, runoff, soil erosion by wind and water, volatility of the pesticide, persistence of the pesticide, plant absorption, use of minimum dosages, etc. All of these factors will be influenced by your choices of pesticide and formulation, application equipment, weather conditions, filling practices, calibration and clean-up techniques.

You must choose the best pesticide: one that will give effective control, be persistent enough to do the job, yet break down when it is no longer needed. Pesticides usually persist longer in soils of high organic content than in light mineral soils. If you are working near water you can choose the pesticide least harmful to aquatic life that is registered for the use intended. Certain herbicides depend on persistence for effectiveness and can cause problems if susceptible crops are planted too soon in the treated area. Many of the chlorinated hydrocarbons -- DDT, dieldrin, aldrin, etc., were highly effective, but so persistent and accumulative that their use has been drastically cut back or prohibited. The choice of pesticide also includes choice of the best formulation. The applicator wants the pesticide to stay within the area treated. Therefore, he will use the formulations that will be less likely to cause drift and may use anti-drift adjuvants.

Even though the pesticide remains in the treated area, it would be wise to check the fences and notify the owners if livestock graze nearby. You should also warn your client about any restrictions on grazing or feeding of the treated crop, so that no poisoning of livestock or contamination of meat or milk results. You may wish to use a less toxic or less limited pesticide if working near livestock.

Here are some tips that you may follow to improve your operation and cut down on local contamination. 1) How do you carry your pesticides and other supplies in your truck or trucks that service your sprayers? Rather than riding loose in the back of the truck they should be enclosed. Built-in lockers are convenient if you can get them, but a locked storage chest will be adequate. 2) You also need a place to hold the empty containers that you don't burn in the field. 3) A first aid kit in the cab of the truck can literally be a life saver. Plastic eyewash bottles that have a flushing action can also be carried in the cab. 4) A container of clean water fastened somewhere on the outside of the truck with detergent and hand cleaner nearby is also worthwhile for washing off spills, splashes or other skin contamination. A faucet or valve on the container will make it easy to control water flow.

5) If you transport pesticides over the highway to sprayers in different locations you may accidently spill concentrates on the highway. Keep a shovel, stiff broom, and neutralizers (Clorox, lime) on your truck. Don't forget to call local police and health officials if the spill is too large for you to handle safely yourself. 6) You should have boots, gloves and a respirator handy if the pesticide you are carrying and applying is toxic enough to require them. This same equipment can also be used for spills of concentrated pesticides in the field.

7) Are you filling from a well? Who else is using it and for what purpose? Use a separate pump with check valves to prevent back siphonage and be sure the filler hose does not dip into the sprayer tank. If you mount the right size hook to hold the filler hose, you won't have to hold it and there will be no chance of its dipping into the tank. Be sure your sprayer doesn't overflow and drain pesticide contaminated water back into the well. If the well you are using is the source of domestic water or for watering cattle, you may want to fill elsewhere. Even if you fill elsewhere, you should take the same precautions (cattle drink from ponds and fish live in streams).

Suppose you do contaminate the well. What then? First, contact your county or state health official. Usually your actions will depend somewhat on the toxicity of the pesticide involved and how tightly it fastens to particles in the water and on the walls of the well. With materials of low or moderate toxicity, the well should be pumped dry, allowed to recover and pumped again. Addition of a charcoal slurry will help absorb the pesticide. Clorox or another chlorine compound may help break down the pesticide. The well should be pumped dry after the addition of any of these absorbents or neutralizers. Domestic and barn plumbing should be thoroughly flushed after the well is decontaminated and before any water is used. If the contamination was of highly toxic materials, a chemical test should be made before the water is used. If the well cannot be purified you may be liable for a new water supply. Prevention of contamination may be vital to your business.

8) Your sprayer filling station can be designed to minimize problems. Frequently filling stations are on pond or stream banks and the natural flow is back into the water. Grading the area to slope away from the water will prevent this problem and allow you to neutralize an unplanned spill so that it does no damage. 9) Another common problem with these areas is disposal of "empty" pesticide containers. Much too often they end up in the water. A trailer, old truck van, or some other storage place, in which used containers can be held safely for disposal, will prevent this contamination.

10) There are two main possibilities for contamination at your storage and clean-up area: chemically contaminated runoff from wash water or fire fighting water, and exposure to yourself or other people. Your core manual tells you how to avoid runoff problems. 11) The right precautions will help you avoid exposing yourself during clean-up or repairs. Dress properly for clean-up as well as for mixing or application. The residue that you scrub off the outside of your equipment may be more concentrated and toxic than the spray itself. Don't scrub the surface with your bare hands or a rag which will soon be loaded with the chemical. Instead use a scrubbing brush with a handle and, if necessary, rubber gloves. Check the label if you are in doubt.

12) Often you need to clean and check your sprayer booms, hoses and nozzles when there is spray material in the tank. Rather than use contaminated

water from your tank you can hook a hose to the discharge side of your spray pump and do your cleaning with uncontaminated water from your domestic water supply. This is particularly convenient if your spray tank has spray mix in it. Remember, however, that the first discharge from the nozzles will be spray mix. Remember also that back siphoning can occur even in pressure water systems if there is a sudden heavy drain on the system.

13) Normally, you will not get inside your spray tank. However, you may have to make repairs that require you to do so. If so, remember that it is probably a highly toxic area. Avoid working alone. Wear full protective gear to prevent both dermal and inhalation toxicity. Even outside the tank welding may generate highly toxic fumes. Use a respirator.

14) Personal contamination or poisoning can also be caused by lying on contaminated ground while making repairs to machinery. Move the equipment to an uncontaminated area, or use a creeper, piece of linoleum or something similar to protect yourself.

As in other areas of pesticide handling, the best preventative for contamination is your own awareness and good judgement.

Specific Use Problems

Some categories of pesticides have special problems that require your attention over and above the usual awareness.

Herbicides and their use are growing rapidly and now represent the largest single group of pesticides used in agriculture. Although, as a group, they are relatively low in their hazards to humans and to wildlife, they are not without hazard, and some are highly toxic. However, it must be remembered that the greatest hazard associated with herbicides is their phytotoxic effect on non-target plants caused by incorrect or inaccurate application. Misapplication of herbicides may occur as a spray drift of droplets, particles, or vapor, as soil contamination resulting in absorption by roots of non-target plants, as excessive soil persistence causing injury to later crops, and as sprayer contamination. All must be avoided!! All produce obvious damage but by the time they are visible it is too late to remedy the cause.

Plant growth-regulating or hormone-like herbicides produce the greatest hazard to non-target plants. Although these chemicals are primarily used to check growth of broadleaf plants, crops such as wheat, oats, barley, milo, corn and turf grasses can be seriously affected as well.

Spray drift of soil-applied non-crop herbicides such as fenac or 2,3,6-TBA can injure sensitive crops such as beans, even when the drift has occurred before planting. All herbicides are subject to drift for considerable distances. Some, however, such as those listed below present a particular hazard to non-target plants from drift. All of them except dinoseb, propanil, and paraquat are of the plant growth regulator type and can cause abnormal plant growth even in trace amounts.

EXAMPLES OF HERBICIDES THAT PRESENT A PARTICULAR HAZARD TO NON-TARGET PLANTS FROM DRIFT

2,4-D
2,4-DB
dicamba (Banvel)
dichlorprop (2,4-DP)
dinoseb
fenac
MCPA
MCPB
mecoprop (Mecopar)
paraquat
picloram (Tordon)
propanil (Stam F-34, Rogue)
silvex
2,4,5-T
2,3,6-TBA (Benzac, Trysben)

Sprayer contamination is also most likely to result from the materials listed above. If the sprayer is used for other purposes, decontamination is a problem. Repeated flushing with water is not a dependable method to remove herbicide residues from any spray tank, pump, hose, boom and by-pass system. Emulsifiable formulations such as esters and oil soluble amines are more difficult to remove than water soluble metallic and amine salts. Wooden tanks are almost impossible to decontaminate. If you must decontaminate, circulate a solution of household ammonia or detergent (1 quart to 25 gallons of water preferably warm) through the sprayer at operating pressure, including hoses, booms, and nozzles. Let stand for several hours, drain, flush, add more water. Test by spraying sensitive plants such as bean or tomato seedlings. Injury will usually appear in 2 to 7 days if the sprayer is still contaminated.

Soil persistence of herbicides is important in selecting an herbicide. You must consider the crops that will follow if problems are to be avoided.

Soil persistence is dependent on many factors including rate, formulation, and method of application of the herbicide, as well as soil type, microbial populations, soil temperature, moisture, and tillage. In general, herbicide breakdown is most rapid in warm, moist soils with good microbial growth; it is more prolonged by cold, dry, sterile soils. Alachlor, butylate, endothall, TOK, paraquat, and silvex are a few examples of some herbicides with relatively short soil persistence (1 to 2 months) based on weed control. Materials like atrazine, benefin, bromacil, dicamba, diuron, picloram, terbacil and trifluralin are examples of herbicides persisting for six months or more.

Special Use Pesticides

Growth regulators, desiccants, and defoliants are chemicals that can be used to improve crop performance, production, storage or handling procedures, rather than to control a particular pest. Slight variations in the methods of use of these chemicals can have significant effects on their performance: the same chemical may produce different or even opposite effects on the same crop, depending on the rate of application and weather conditions, as well as differences in age, stage of development, rate of growth, and vigor of the plants.

Growth Regulators

Growth regulators may be used in very small amounts either to stimulate or to reduce growth, flowering, or fruiting. They are used in the production of fruits and nuts, vine and small fruits, vegetables and field crops. Materials such as napthalene acetic acid (NAA), napthaleneacetamide (Amide), naphthylpthalamic acid (NPA), and carbaryl, when applied after bloom for blossom thinning, upset the physiology of the flower or fruit causing the seed to die and the fruits to drop from the tree. Other materials such as dinitros, used in bloom, are caustic and burn some of the flowers off. Some growth substances may be used to improve fruit set, prevent excessive fruit drop, or to control the time of fruit maturity. Other materials have been used to increase bloom the following year. Because of the sensitivity of plants to these chemicals and the small quantities used, extra precautions must be carefully observed to use precisely the right amount of chemical at the right time on the specific varieties intended for treatment. In these applications equipment calibration is vital. Application is usually made as a foliar spray, a soil drench or by bark injection. Particular care must be taken to avoid drift with foliar sprays and timing is usually critical.

Sprout inhibition is another form of growth regulation, in which chemicals are applied to crops such as potatoes and onions to prevent sprouting in storage. Inhibitors should not be applied to potatoes or onions intended for use as seed. Treatments may be made in the field prior to harvest (i.e., maleic hydrazide to potatoes or onions) or in storage after harvest (Chloro IPC as a dip or spray during grading or as a vapor or aerosol applied in the ventilation system of the storage).

Growth regulators also include chemicals which break dormancy in plants or plant parts, and speed up root formation and elongation. This category does not include fertilizers and plant nutrients although they are sometimes sprayed on crops -- particularly fruit trees. Do not combine fertilizers or plant nutrients with pesticides.

Desiccants and Defoliants

Some chemicals are used to cause the leaves to drop from crops such as cotton, soybeans, or tomatoes to make harvest easier without killing the plants. Such chemicals are called defoliants. Other chemicals, desiccants, are intended for speeding up the drying of plant parts to aid in the harvesting of some seed crops (alfalfa, clover, sorghum), potatoes, dry beans and nursery stock. Frequently the terms are used interchangeably and depending on the amount applied some defoliants also act as desiccants. Sometimes mixtures are used (i.e., cotton) and these combination materials are called "harvest-aids".

Some of the advantages of using defoliants or desiccants are: 1) reduction of disease or insect populations, 2) killing of weeds which interfere with harvest, 3) aid to and simplification of mechanical harvesting, 4) quality improvement, 5) reduction of storage crop disease, 6) reduction of the moisture content of seed, and 7) yield increases. Disadvantages may be: 1) a reduction in yield and quality, and 2) toxic residues.

Complications can result from the use of these materials, so you must take great care in their selection and use. For example, the use of some materials on potatoes causes discoloration at the stem end of the tubers.

Other materials cannot be used on potatoes that are to be stored without increasing the risk of storage rot. Slower kill of the vines may be preferable to a faster kill. Other factors such as soil moisture, cultural or climatic conditions, stage of growth (flowering plants are not easily desiccated), and stage of maturity are important considerations. Be sure you have all the information needed before using any of these materials. Injury is readily visible, even if minimal. If additives are specified on the label, use only those recommended. Crops treated with a desiccant generally cannot be used for grazing, and many do not permit use of the seed for food, feed, or oil purposes. Before using a defoliant or desiccant on a crop, be sure that the remaining part of the crop is not going to be used as food or feed.

Soil Pesticides

The soil is the most complex medium you will treat for the control of pests. Soil treatments include the use of variously formulated insecticides, fungicides, nematicides, and herbicides. Success in soil pest control requires: 1) knowledge of the pesticide: volatility, water solubility, absorption rate and rate of breakdown; 2) knowledge of the characteristics of the soil being treated: sand, silt, organic matter content, texture and structure, temperature, moisture content, and air movement; 3) requires knowledge of the pest: its stage of development and its susceptibility to pesticides. An understanding of these factors and how they relate to each other is essential.

Soil pesticides can be grouped in two categories -- volatile and nonvolatile.

Volatile - Fumigants

Those that are volatile are called fumigants. They vary from broad-spectrum materials to those that are very specific; from those having very short residual effectiveness to those with longer residual effectiveness; and those which are highly volatile to those having low volatility. Some are available under pressure as liquids but are released as gasses under covers (tarpaulins). Others are liquids but vaporize after being placed in the soil.

The dose of a soil fumigant necessary to kill pests depends on the concentration of the chemical in the soil and the amount of time the organism is exposed. This is influenced by soil conditions -- soil type, moisture level, etc. Recommended rates are selected to perform satisfactorily over a wide range of soil conditions.

The effectiveness of fumigation also depends upon the temperature and moisture of the soil and the depth to which it is treated. If the soil is too warm or too dry and the fumigant injected too shallow, 6 inches or less, the gas may escape too fast for good control; and if too cool, diffusion may be too restricted to obtain good control. If too wet, the water occupies most of the air space, more fumigant dissolves in the water, the fumigant that is left as a gas moves very slowly, distribution is poor, and control is poor. Soil fumigants perform best when soil is only moderately moist, somewhat drier than seedbed condition, and the soil temperature is between 50° and 80°F. Frequently a fall treatment provides better results than a spring treatment because of more favorable temperature/moisture relationships in the fall. When applied by injection, the fumigant should be placed deeper than 6 inches. The soil surface should be sealed by some effective method of soil compaction. When the fumigant is applied as a drench, the soil surface should be sealed by irrigation, with care to avoid excess water.

Soil structure and condition also influence the effectiveness of fumigants. Generally fumigants move faster in loose and sandy soils than in clay or compacted soils. Control will be better in well-tilled soil with high content of organic matter than in poorly-prepared cloddy soil. Highly organic soils may absorb or "tie up" the fumigant, and soils with plant residues (stalks, vines, etc.) may protect nematodes and other pests from the fumigant, as well as reducing effective injection and seeding.

Aeration time (the time needed to allow the fumigant to leave the soil) is important to avoid injury to the crop. It varies with the chemical, soil temperature, moisture, texture, and the crop to be planted. Fumigants such as ethylene dibromide, methyl bromide, and dibromochloropropane (DBCP), leave appreciable residues of bromine in the soil. These residues are toxic to some plants (onions are very sensitive) and are taken up by others (many forage and feed crops). DBCP causes severe damage to tobacco, potatoes, sweet potatoes, garlic and some types of pepper.

Some fumigants applied under tarpaulins temporarily reduce the populations of beneficial microorganisms as well as pests. To compensate for a temporary lack of nitrifying bacteria, nitrate fertilization after fumigation is required. To compensate for a lack of mycorrhizal fungi, phosphorus fertilizer is placed near the seed, as in corn fertilization.

Non-Volatile - Non-fumigants

The non-fumigant soil pesticides are non-volatile and vary in their characteristics: from high to low water solubility; from non-systemic to systemic in their activity; and from little (short residual) effectiveness to long (residual) effectiveness.

Non-systemic pesticides must be directly placed on the site of action (carried by water for instance) or must depend on the plant to grow to the material. Pesticides having systemic action may be translocated upwards or downwards through the plant, or in both directions; therefore, it is not necessary to apply the pesticide directly to the part of the plant to be treated.

Non-fumigant soil pesticides are usually dependent upon the presence of soil moisture. Moisture is often needed to activate or release the pesticide, to move or distribute it into or through the soil, and to allow absorption into the plants. Materials that are highly water soluble need less water than products of low solubility in water. Those materials having low water solubility, high evaporation rates, sensitivity to breakdown by sunlight, or high absorption rates on soil particles, usually require mechanical incorporation (physical mixing) into the soil, regardless of rainfall or irrigation.

As with fumigants, non-fumigant soil pesticides are less effective or require higher rates of application in soils high in organic matter, in fine clay or silt soils, and at temperatures less than optimum. Best results can be obtained if you know the soil type and organic matter level of the fields you treat. For future jobs, keep records of materials and the results obtained.

Safety

Pesticides vary in potential toxicity to the applicator and the environment. The fumigants are generally classified as moderately toxic, whereas the non-volatile pesticides range from extremely toxic to relatively non-hazardous. It is important that the toxicity of each pesticide be known before use. The label will tell you, but in the absence of such information, any pesticide should be considered extremely toxic. Proper safety equipment and clothing should be worn when highly toxic pesticides or pesticides of unknown toxicity are being used. Likewise, potential environmental pollution should be recognized, and proper precautions taken. Again, the label will warn of hazards, and list the precautions that should be taken.

Combinations or Mixtures of Pesticides, Mixing and Compatibility

Mixing pesticides in the spray tank is an old and widely used practice. A mixture of an insecticide and fungicide or an insecticide and an acaracide is often used on fruit and vegetables to save an additional application. Different herbicides are sometimes mixed to broaden the spectrum of activity. A grass killer may be combined with a broadleaf killer, or a product particularly effective against one particular species may be added to another of more general activity to broaden the spectrum of effectiveness. This is practiced with insecticides as well as with herbicides. Sometimes a mixture of products is used to increase effectiveness against a single pest species. Many of the newer pesticide labels specifically list the mixtures that can be made with that pesticide.

Under present federal regulations, uses of pesticides inconsistent with (or not mentioned on) the labeling are a misuse and unlawful. The legislative history shows, however, that it was the intent of Congress that EPA be reasonable in interpreting and enforcing misuse provisions. Accordingly, EPA has interpreted the legality of tank mixing of pesticides and set a policy that will be in effect until modified by further statements or regulations.

Tank mixes may fall into one of three acceptable categories:

Category 1 - Instructions provided on label

instructions for tank mixing are provided on one or more labels of EPA registered products. Such uses are fully consistent with the label and no further clarification is needed.

Category 2 - Registered intrastate

tank mixes are covered by state registrations. Such registrations are valid until replaced by EPA registrations scheduled to be completed by October 1976. If a product use is cancelled or suspended from interstate commerce at the federal level before such time, the state registration is also cancelled. To date the only products involved are DDT, aldrin and dieldrin. Otherwise state use registrations are valid.

Category 3 - Recommended by state agencies or with a history of use

tank mixes have been tested and recommended by Cooperative Extension, state agricultural experiment stations, state departments of agriculture, or are recognized as common agricultural practice. These are acceptable provided the dosage rate of any pesticide in the mix does not exceed the label instructions for the same product used singly, and provided that the label does not specifically instruct against such a mixture.

EPA has not reviewed those uses in Categories 2 and 3. While such uses are legally acceptable as to consistency with label instructions, this does not mean that EPA has approved them in regard to either efficacy or human and environmental safety data. Therefore the user applies them at his own risk.

If adverse effects are observed from any particular tank mix EPA may consider these uses on a case-by-case basis and rule them inconsistent with the label.

In summary, tank mixes and serial applications are ruled consistent with the label and recommendable if:

a) the label specifies such uses,
b) there is a state registration for such uses, or
c) such uses are recommended by state agencies or are common agricultural practice.

Even when pesticides are approved for use in a mixture, problems may still result. Formulations of a particular pesticide vary from one product to another, and incompatibility may result from the different wetting agents, solvents, and other additives in them. Liquid formulations are particularly susceptible to incompatibility problems due to the many additives they usually contain. Incompatibilities are expressed in different ways, but a crystalline precipitate or a gelatinous mass is common, which would require time to clean out plugged nozzles, screens, and regulators. Another common result is a break in the emulsion in which the different ingredients separate out as would oil and water. This is the result of the emulsifier being destroyed, and spray injury is likely to result. Sometimes the addition of soluble salts to the spray tank will cause an emulsion to break. Separation can also take the form of clumping of particles together. This is called agglomeration.

Incompatibility can also result in lessened activity of the combination although no visible problems can be seen. The combined materials inactivate one another, and the resulting mix will be less effective.

Hardness of the water may also affect a pesticide or mixture of pesticides. Phosphate and carbamate materials are more susceptible to high alkalinity than other pesticides. The addition of lime, lime sulfur, Bordeaux mixture or other highly alkaline materials may cause decomposition, loss of toxicity, or phytotoxicity.

Combinations of oil or petroleum solvents with organic chemicals frequently are very injurious to plants. Many emulsifiable concentrates are formulated with petroleum solvents and fall into this category. When two emulsifiable concentrates are combined, the pesticides may be compatible but the solvents or emulsifying agents may not be and injury may result.

Many cases of incompatibility are reported for combinations of emulsifiable concentrates and wettable powders. Sometimes one or both pesticides precipitate or fall out of the mixture and spray injury to the crop is the frequent result. In other cases, mixing may cause excessive residues although no precipitation is noticeable in the tank.

Most agricultural emulsifiable sprays are oil-in-water emulsions producing small particle sizes. Invert emulsions, water-in-oil, are usually less desirable for insect and disease control but, because of the larger droplets, may be more desirable for herbicides. When difficulties in emulsifying an oil- or pesticide-in-water spray are encountered, they can usually be corrected by starting with just enough water to cover the agitator, then starting the engine and running the agitator and the pump at full pressure to force the liquid through the by-pass return to the tank. If an additional or separate emulsifier is to be used, it should be added to the tank before adding the pesticide or oil. Allow the pump to run for two or three minutes. Once this emulsion is formed, add the rest of the water to fill the tank while the pump and agitator are running. Invert emulsions usually require special equipment in which a special mixing chamber is used between the pump and the nozzle.

Although incompatibility may still be a problem, it can frequently be reduced to the minimum by:

1) Using formulations produced by the same manufacturer.

2) Keeping the equipment clean and well drained.

3) Never putting pesticides in an empty tank. The tank should always be partially filled before adding the pesticide.

4) Never combining concentrates, but diluting them first.

5) Mixing wettable powders with water to form a slurry before they are added to the tank (unless you have an inductor system).

6) Adding wettable powders to the tank before the emulsifiable concentrates.

Mixtures of Pesticides and Fertilizers

Many of the principles for using tank mixtures of pesticides also apply to fertilizer-pesticide mixtures. The most important point to remember is that such mixtures, either wet or dry, should be handled as pesticides, not fertilizers. In some states there are specific regulations governing use of fertilizer-pesticide combinations. Check your local state situation, or if you cross state lines -- make sure you are operating within regulations.

Pesticides are precision tools. The total quantity of a pesticide in the tank may be less than the accepted variation in fertilizer application which may vary from a plus or minus of 10 to 15 pounds per acre. Timing, placement, and distribution are frequently different for pesticides and fertilizers. Compromising one requirement may limit the usefulness and safety of the mixture.

Where tank mixtures are to be used, make sure that agitation is adequate to maintain the suspension. Suspensions also require about one to two gallons of spray carrier for each pound of product to be suspended. Some products are specifically formulated for use in fertilizer mixtures. Others specify the need to check emulsion stability and add a compatibility agent if needed.

Serial Applications of Pesticides

Serial applications of pesticides are applications in which the pesticides are applied individually but following one after another. Although the time is generally limited to a few days, it can be longer. Regulations governing serial applications are the same as for tank-mixtures of pesticides. Problems arising from incompatible serial applications may be plant injury, loss of effectiveness of one or both pesticides, excessive residues, etc. This is particularly true if oil is applied before or after a pesticide or nutrient spray.

Adjuvants or Spray Additives

Pesticides, whether emulsifiable concentrates or wettable powders, are formulated for general performance purposes under average conditions. For many jobs they perform satisfactorily, but there are also many situations where they fall short of the desired effect. For example, in very hard or soft waters, a formulation may have too little or too much emulsifier, with the consequent problems of difficulty in mixing or of excessive foaming. A formulation may evenly distribute a pesticide on the leaves of crops such as beans and potatoes satisfactorily, but on the waxy leaves of cabbage, cauliflower, or onions, the spray, instead of spreading as an even film over the leaf surface, may form small, round droplets. It then runs off of the plant and onto the ground, leaving no deposit to protect the plant. The addition of a surfactant to the spray tank will solve this problem. Recently it has been common to add to herbicides materials which improve their effectiveness by increasing their ability to wet and penetrate treated surfaces. A substance added to the spray mixture to aid or improve the performance of the main ingredient is an adjuvant.

Adjuvants may be added to the spray mixture to:

1) Improve the wetting of the foliage or the pest.

2) Change the evaporation rate of the spray.

3) Improve the ability of the spray deposit to resist weathering.

4) Improve the penetration, absorption and translocation of the pesticide.

5) Adjust or buffer the pH of the spray solution increasing the effectiveness and longevity of alkaline sensitive pesticides.

6) Improve the uniformity and amount of the deposit.

7) Improve the ease of mixing or compatibility of the spray mixture.

8) Increase the safety from spray injury to the crop.

9) Reduce the drift hazard to neighboring crops.

10) Improve physical properties of the mixture -- i.e., anti-foaming agents.

Depending upon their intended use, adjuvants are called emulsifiers, wetters, stickers, extenders, spreaders, deposit builders, film formers, buffering agents, thickeners, penetrants, foaming agents, anti-foaming agents, etc.

Adjuvants are highly active materials. In most cases, a very small quantity will have great effect. You should be careful to use only the amount recommended. Too much adjuvant may be just as bad as too little -- it makes little difference whether the pesticide runs off the foliage because it balls up or because it forms too thin a film on the foliage. Also, too much adjuvant may cause herbicide spray to lose some of its selectivity and injure plants normally tolerant of it.

Regulations require spray adjuvants, for use with pesticides, to be registered and carry an EPA number and either to be exempt from the requirement of a tolerance or to have a tolerance established.

Proper selection of the adjuvant for your job is of the utmost importance.

II. PESTS

You can't solve a pest problem if you don't know the pest. Accurate diagnosis of the pest and its damage is essential in deciding what to do. If you are familiar with the pest you may decide to do nothing, because you know that most of the injury has already occurred, that the potential damage is less than the cost of chemical treatment, or that no effective chemical treatment is available. Additional damage caused by driving equipment through the crop may be greater than that caused by the pest. For further discussion on specific pests refer to the chapter in this manual that deals with your commercial category.

Identification and Diagnosis

Identification of the pest or pest damage is the most important step in controlling the problem. Thorough knowledge of the crop and its growth characteristics is essential. Otherwise, evidence for the presence of and damage by a pest may go undetected. To know and to recognize the causes of poor plant growth and the signs of pest injury require years of experience. This is one reason why people who diagnose pest problems prefer to work with a small number of commodities such as vegetables, forests, or turf. Even then, there is no substitute for experience; the accurate diagnosis of plant ailments is a skill requiring much time and effort to develop. Generalizations can be made, however, that will help identify the cause of some ills of plants.

Plants may be injured by animals such as insects and rabbits, by other plants (weeds), by fungi, bacteria, viruses and mycoplasmas, by environmental imbalances such as drought and nutritional deficiency, and by chemical injury such as air pollutants and sprays (see below).

Possible Causes of Injury to Plants

Animals	Other Plants	Microorganisms	Other
Birds	Dodder	Bacteria	Air pollutants
Dogs	Mistletoe	*Fungi	Drought or excessive moisture
Insects	Moss	Viruses	Lightning, wind & hail
Mites	Weeds	Mycoplasmas	Mechanical injury
Millipedes	Algae	Viroids	Mineral deficiencies
Nematodes			Spray injury
Rabbits, mice, moles, rats & others			Extreme temperature
Slugs and snails			Oxygen deficiency in soil

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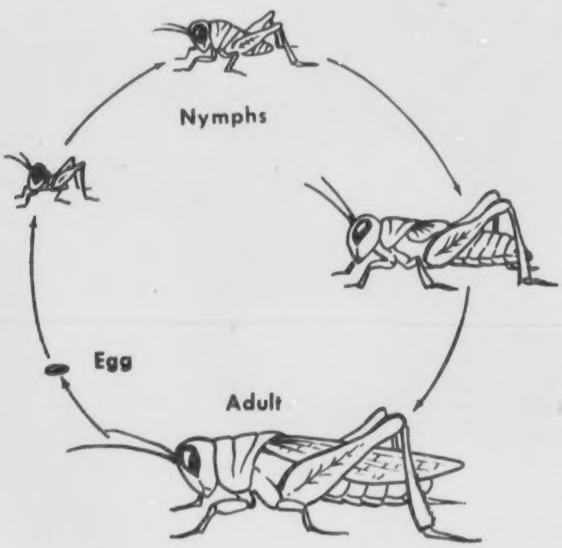
*Some fungi may be large in size.

The cause of damage is often revealed by careful observation. For example, a canker disease may have girdled a twig or limb causing the leaves to wilt or die. However, one must not only look at the leaf, but one must look carefully along the twig or limb to find the cause. Or, an insect may be eating the plant roots -- the symptoms first appear on the leaves, but until the roots are examined, the cause cannot be correctly identified. With careful observation, knowledge of the plant's history, and a general knowledge of possible causes within the geographical area, plant ills can frequently be diagnosed without the need of a specialist.

Possible and correct diagnosis of the problem is essential for effective control. Identification of pests is based on a thorough knowledge of the host and symptoms of damage, the part injured, time of year, etc. Identification of damage by location and host will be given in this manual following a brief treatment of some characteristics of the different pests.

1. Insects

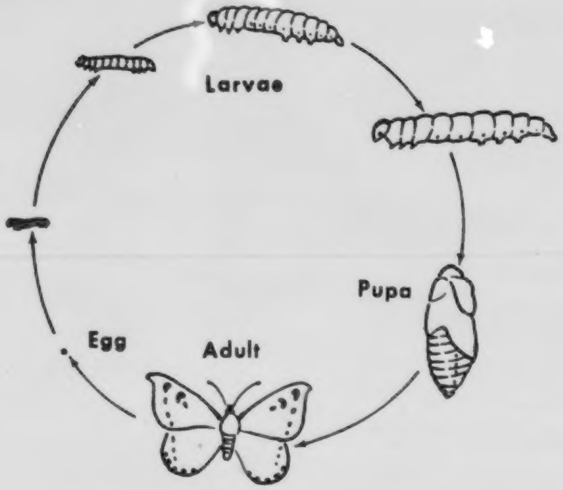
Most insects injurious to plants have a life cycle in which either: 1) the newly hatched insect differs from the fully grown adult primarily only in size -- the young or nymphs look like the adults in form, except that the wings may not be developed, and they feed in the same places (see illustration below):



GRADUAL METAMORPHOSIS

Insects with gradual metamorphosis change shape gradually. Wings develop externally and as growth takes place, the nymphs look more like the adult.

or 2) the adults and young are not alike -- the young or immature forms are wormlike, usually called larvae or caterpillars, while the adults are moths, butterflies, flies or beetles (See illustration). The damaging stages of insects with this type of life cycle are most often the larvae which may be found when the adult stage cannot. Many times insects found on injured plants are not the primary cause of the injury, they just happened to be there.



COMPLETE METAMORPHOSIS

Insects with complete metamorphosis go through four stages of growth. None of the young looks like the adult. There is a great change in shape when the adult emerges from the pupal stage.

Ways Insects Injure Plants

a. Chewing: Insects with chewing mouthparts usually leave obvious feeding wounds such as notched leaves, tunnels or wounds in wood, bark, roots, stems, fruit, and seeds, or mining in the leaves. Symptoms: ragged leaves, holes in wood and bark or in fruit and seed, serpentine mines or blotches in leaves, wilted or dead plants, or presence of "worms".

b. Sucking: Some insects with sucking mouthparts may not leave obvious feeding wounds since they puncture the leaf or fruit to suck out the sap and cell contents, and to inject toxins into the plant. Symptoms: leaves usually off-color, evidence of scorch or hopper burn, wilted or misshapen foliage and fruit.

c. Oviposition: Scars can be formed on stems, twigs, bark, or fruit as a result of injury during egg laying. When certain insects have laid eggs in parts of plants, galls may form as the young insects develop. Galls are growths that resemble tumors and may form on leaves, twigs, buds, and roots. They disfigure plants and some may cause serious damage.

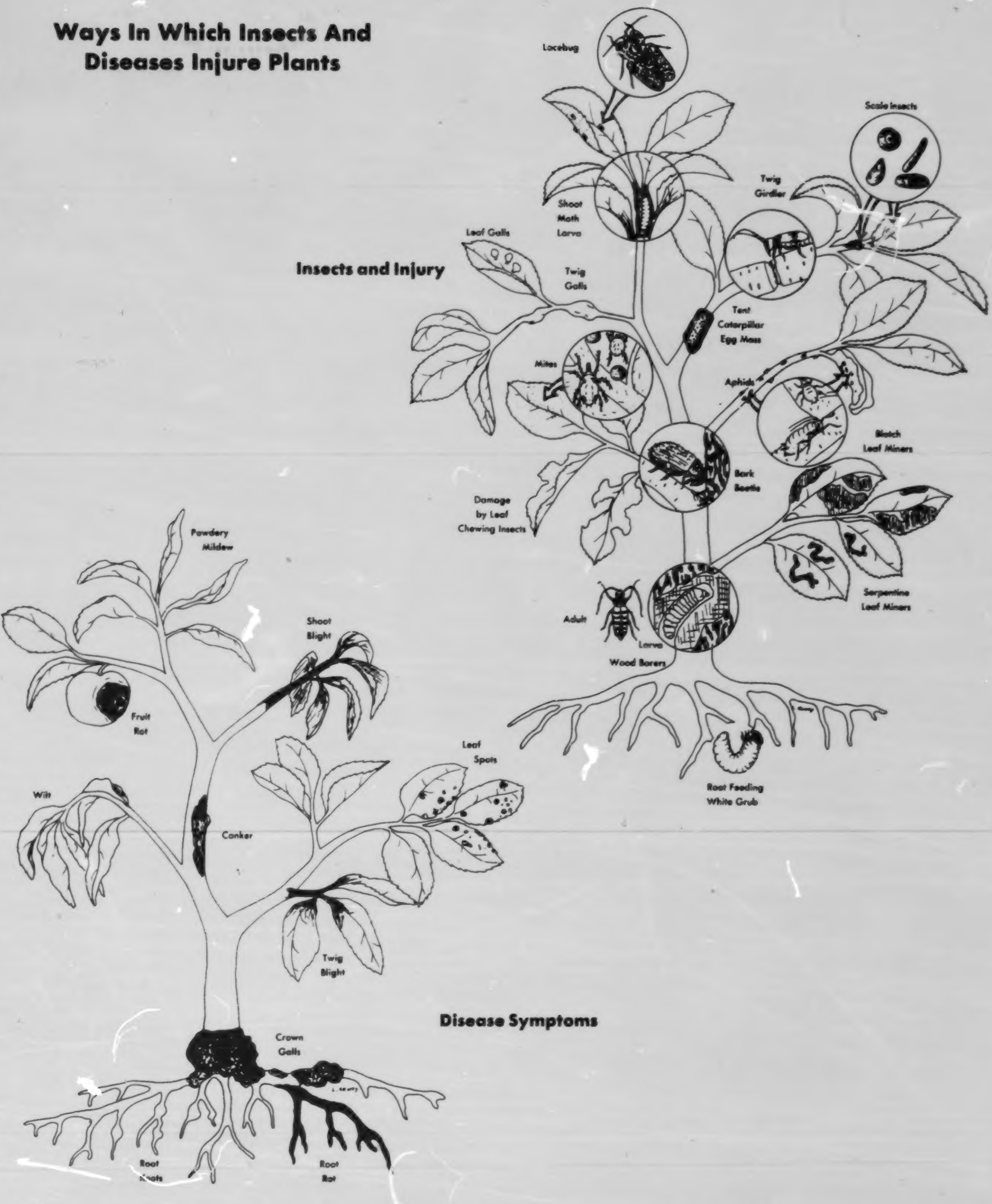
d. Vectors of diseases: Insects may carry plant pathogens on their body or inject them with the mouthparts while feeding from plant to plant, e.g., elm bark beetle - Dutch elm disease; various aphids -- virus diseases; bees -- fire blight. Symptoms: leaves wilted, dwarfed, foliage off-color.

e. Excretions: Honeydew deposits secreted by some insects lead to the growth of sooty mold (a black fungus), and the leaves are unable to perform their manufacturing functions. This results in a weakened plant. Symptoms: sooty black areas on leaves, twigs, branches, and fruit.

2. Diseases

Unlike insects you cannot always see the organism which causes the disease. You can see the signs and symptoms of its presence but in the early stages these may be difficult to identify. Some diseases are caused by non-living agents such as air pollution, drought, etc., and are called non-infectious plant diseases. Living causal agents are called pathogens and cause infectious plant diseases. Sometimes they can be easily recognized with the naked eye. However, in most instances you cannot see the pathogen without the use of a microscope. You see only the symptoms. Knowledge of the host plant, its diseases, and signs or symptoms are very important in identifying them in the field. Prevention of further spread of a disease is a primary concern. Once infection occurs, favorable moisture (rain, dew, etc.) and temperature conditions may cause rapid spread and damage. Leaf spots and shoot

Ways In Which Insects And Diseases Injure Plants


Insects and Injury
Lacebug
Scale Insects
Twig Girdler
Shoot Moth Larva
Leaf Galls
Twig Galls
Tent Caterpillar Egg Mass
Mites
Aphids
Blotch Leaf Miners
Bark Beetle
Damage by Leaf Chewing Insects
Serpentine Leaf Miners
Adult
Larva
Wood Borers
Root Feeding White Grub
Disease Symptoms
Powdery Mildew
Shoot Blight
Fruit Rot
Leaf Spots
Wilt
Canker
Twig Blight
Crown Galls
Root Knots
Root Rot

blight may spread very quickly under favorable conditions, while wilts and root rot diseases may spread more slowly. Early and accurate diagnosis is vital to successful control.

Ways in Which Infectious Diseases Damage Plants

a. Disrupt water-conducting cells and plug the vascular system which conduct food and water throughout the plant. Symptoms: yellowing, wilting, dead branches.

b. Destroy or damage cells of leaves and sometimes fruit. Symptoms; blotch, scab, black spots on leaves, fruit rot.

c. Destroy or damage roots and root hairs. Symptoms: wilting, yellowing or stunting of plants, rotted roots, death.

d. Cause formation of galls and overgrowths. Symptoms: unusual growths on flowers, twigs, and roots.

e. Decay of wood.

f. Damage to flowers, fruit and seeds causing them to rot. Examples: fireblight, bacterial rot of potato.

g. Damage or death of plant tissues from production of toxins.

3. Nematodes

Nematodes are very small roundworm-like animals, whose young resemble the adult except for their smaller size. Those which damage plants live in the soil and are round, thread- or eel-like worms which are so small that they canNOT be seen without the aid of a microscope. Many types of nematodes cause no damage, but others feed on or in the roots, bulbs or stems, or on the leaves or seeds of plants. Special training is necessary to identify them. Symptoms of disease caused by nematodes are usually localized in one or more spots in a field or turf area, but the nematodes involved must be isolated, identified, and numbers estimated before the symptoms can be accurately evaluated. An examination of plant roots and soil taken from around the roots can help determine whether nematodes are wholly or partially responsible for poor plant growth.

Ways in Which Nematodes Injure Plants

a. Mechanically disrupt water conductive tissues or induce cell abnormalities resulting in inefficient translocation of water and nutrients. Symptoms: wilt, loss of color, yellowing of leaves.

b. Destroy or damage roots and root hairs. Symptoms: stunted growth, poor vigor; roots with necrotic spots or dead root tips and/or stunted roots, or loss of feeder roots.

c. Causes gall formations on plant roots which will reduce vigor in the plant. Symptoms: root galls -- be careful not to confuse with nitrogen fixing nodules on legumes.

Nematode population levels for preplant treatments have limited meaning. Knowledge of their damage to previous crops is more useful. Usually the combination of one or more of the following factors are necessary to cause economic damage.

1. Optimum conditions for nematode build-up.
2. Plant stress conditions.
3. Nematode disease complexes.
4. Root or tuber quality (root crops).

The principle nematodes and crops of economic importance are as follows (there is considerable variation in species and host specificity):

Nematodes	Crops
Root-knot	A very wide economic host range (numerous species and specificity).
Root lesion	Most crops, but especially perennial crops.
Cyst	Sugar beets, crucifers, soybeans, potatoes, cereals, rice (species and strain specific)
Citrus	Grape
Ring	Primarily perennials
Dagger	Primarily perennials
Sting	Corn, sorghum, and grasses

For further information on specific nematode problems contact your local Cooperative Extension agent for the necessary information.

4. Weeds

Familiarity with two major groups of weeds, narrowleaved weeds and broadleaved weeds, is important in selecting the proper herbicide.

Narrowleaved weeds include all grasses, sedges (nutsedge), rushes, bulrush, cattails and many other plants. All have leaves with parallel veins and are easily recognized (monocots).

Broadleaved weeds is the larger group of the two and includes mustard, dock, smartweeds, pigweed, purslane, field bindweed, blackberries and many others. The veins in the leaves of this group are not parallel but are net-like (dicots).

Ways in Which Weeds Injure Plants or Affect Land Use

a. Reduce yields -- competition for moisture, light, nutrients.

b. Reduce crop quality -- weed seeds, dockage, weeds in hay, straw, etc.

c. Increase production costs -- additional tillage, cultivation of nursery crops; prolong precommercial period in plantations.

d. Increase labor and equipment costs -- machinery wear and tear, etc.

e. Insect and disease carriers or hosts -- e.g., wheat stem rust, corn borer, pine needle rust, and numerous viruses.

f. Poisonous or irritating to animals or people -- cocklebur seedlings, poison ivy, hay fever, etc.

Collecting Specimens for Identification

If you are unable to identify the pest or the damage from the information you have, you may have access to an authority who can come to the field to identify the damage or pest. If this is not possible, you may wish to collect a sample to send him. No matter how much experience you have had, some problems will require further investigation and you will want to collect specimens. Directions for sampling and shipping are available from your local Cooperative Extension agent.

Economic Considerations

Economic injury levels depend on the amount of damage that can be tolerated rather than on pest population levels. In some instances the presence of even a small pest population may result in too much damage, while in other cases extensive populations may not cause significant injury. Sometimes the pest is very conspicuous, but may not be affecting crop yield or quality. The number of pests that can be tolerated varies widely even for the same species in different areas on the same crop and at different stages of crop maturity. The presence of an insect is not necessarily an indication of economic threat to the crop. In fact, low numbers may be beneficial or necessary in maintaining the parasites, predators, or pathogens of the pest. In most situations, complete control or eradication of a pest is not necessary.

When damage to quality, yield, or longevity is threatened and other factors such as parasites, predators, weather, etc. will not prevent it, pesticides will be needed. This is often referred to as economic threshold or damage threshold. Economic threshold levels are not always available for a given crop, pest or locality. The decision to apply a pesticide or not is usually based on past experiences and knowledge of the costs or risks versus benefits to result from control. Costs of damage that will result without control must be weighed against the cost of control. In making this decision, one must consider the following questions:

1. Is the pest population approaching levels that may cause economic threshold damage?
2. Are natural controls (parasites, predators, weather, etc.) present and likely to reduce the population before economic loss results?
3. Will the costs of the pesticide and the labor needed to apply it be less than the gains to be made?
4. What effect will the pesticide have on the environment and the beneficial non-target animals?
5. Can the crop be harvested before damage is serious?

The dollar return from control should be greater than the cost of control. Example: Alfalfa can recover after sustaining substantial damage from the alfalfa weevil. Or, it can be harvested before serious damage results. But, a little patch of late blight in a field of potatoes or tomatoes is a warning of serious damage to follow. Any good commercial applicator should be able to advise his client and carry out the necessary control procedure. Example: The control procedure should result in production of a crop or preservation of a forest stand where otherwise this would be lost. Most often there is no easy way to estimate cost benefit ratios in dollars. But you should at least be able to identify specific benefits that will result from control of a pest, so these may be weighed aginst cost plus any possible adverse effects of the procedure.

When damage becomes noticeable, the best timing for control procedures is usually already past; you may have to accept the damage that year and wait until the next to apply effective control measures.

Life Cycle

A thorough knowledge of the life cycle of the pest is important in making the decision as to whether or when to take control measures. Most, if not all, pests are most readily controlled at one particular stage in their development. The treatment for many pests must be applied before their damage is noticed. Example: most fungicides are protectants and must be on the plant or in the soil as a protective barrier before spores or mycelium of the pathogenic fungus contacts the plant. Most infection occurs under moist conditions. So, it is important to spray before rains come, not afterwards. Knowledge of the disease cycle is a key to proper application of preventative fungicides.

Preemergence sprays for weeds and preventative sprays for corn earworm based on egg observations, are other examples of the value of knowing life cycles. Once the earworm is in the ear it is difficult to kill and the damage is already done. Other pests may already be gone by the time their damage is noticed. Spraying is then a useless exercise and may harm beneficial forms. If you are not familiar with the life cycle or disease cycle and do not bother to look it up, you are not in a position to make the right judgements.

The proper control measure depends upon the biology of the insect, disease, or weed. If an insect is held partially in check by parasites, you may wish to use less pesticide for a slightly lower degree of control, so that the parasites will survive. For this reason, forest stands with low population of defoliating insect such as gypsy moth, and alfalfa fields with low populations of alfalfa weevil may be left untreated. In terms of disease, computerizing observations of temperature, rainfall, and relative humidity during the growing season has already led to an operational system for forecasting the occurrence of potato late blight. Fungicide sprays can be withheld or applied according to this forecast which is based on the biology of the disease. In one area this system saved the cooperating growers four sprays in one season. Knowledge of this disease cycle then, has led to financial saving, larger yields, reduction of crop injury by equipment, better blight control with less storage losses, and an appreciation of the professionalism of the commercial applicator. Since most fungicides must be applied before the plant is infected (protectants) rather than after the plant is diseased (eradicants), a complete knowledge of the particular disease is necessary for effective control.

An understanding of the growth habits of weeds is also a requirement for making judgements about chemically treating with herbicides versus cultivation, rotation, or other such practices. Part of the weed population in a given field can often be controlled by cultivation, but weeds within seedbeds or surrounding planting spots often must be controlled by application of an herbicide.

Other Methods of Control

You should not fail to suggest supplemental cultural practices to your growers. One such practice is crop rotation. When a successful rotation program is followed, a pest specific to one crop will not carry over to the following crops. For example, potatoes should not be planted following sod if the white grub complex is present.

Sanitation practices such as cleaning up cull piles and plowing down old stubble are a definite help in eliminating overwintering or off-season sources of both insects and plant diseases.

The use of resistant varieties of food and feed crops can be practiced by everyone from the home gardener to the large agricultural producer. This concept has been followed for many years in the field of plant diseases. Now plant varieties resistant to insects are being produced, and experimental data is indicating varietal resistance of potatoes and tomatoes to weed competition. Most growers already tend to plant disease resistant varieties, since these are the ones commonly recommended and sold.

Such supplemental practices should not result in loss of business. There is plenty of work for competent commercial applicators; indeed many have problems meeting their obligations. But you can suggest ways in which your customers can aid in pest control, their businesses should be more efficient and profitable and your reputation and profits should grow with theirs.

III. PESTICIDE APPLICATION EQUIPMENT

Agriculture, Forestry, Ornamentals, Shade Trees and Turf

The equipment used in applying pesticides varies with the crop or other target, the type of application, the pest to be controlled and the formulation used. There are many different types, including granule spreaders, hydraulic sprayers, boom sprayers, airblast sprayers including mist blowers, soil fumigation machinery, and tarpaulin fumigation. They all have one requirement in common; they must apply the right amount of pesticide equally over the target area, and you must know at what rate they are applying. You know this as calibration.

Too little, uneven, or too much deposit are all inefficient use of material resulting in insufficient control, spotty control or excessive residue, respectively. Proper adjustment and calibration of the equipment can prevent needless waste of pesticide chemicals by depositing the required amount on the target.

The total deposit laid down on the target, excluding effects of drift or evaporation depends on:

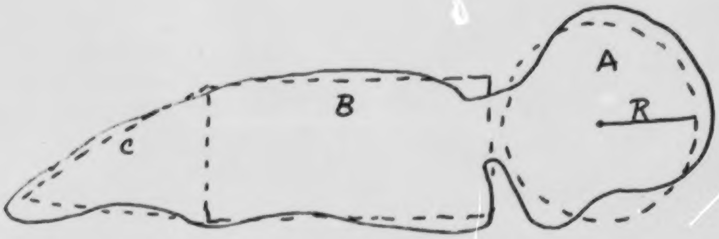
-- The concentration of pesticide in the tank. When spraying with a single nozzle or gun to the point of runoff, this is the important consideration.

-- The rate of discharge.

-- The speed at which the equipment travels.

-- The area covered (the swath width on turf, field or row crops, the distance between rows for fruit trees, the size of shade trees).

The total area (square feet) of rectangular or square areas to be treated can be determined by multiplying the width (W) by the length (L) of the area (W X L - area sq. ft.). Determining the area to be treated of irregular shaped areas such as golf greens is more difficult. One method is to determine the general shape of the area, then impose known shapes (circles, triangles, rectangles, and squares) over segments of the area where appropriate (see example below). The area in each shape is determined and added to the rest to obtain the total area to be treated.



Area A is a circle
Area = 3.14 X R^2
(R = 1/2 diameter)

Area B is a rectangle
Area = L X W

Area C is a triangle
Area = 1/2 X B X H (Base X Height)

Most of you already have your application equipment and are familiar with its performance. However, if you are buying new equipment, you will want to get some that is properly set up for the bulk of the work you intend to do. You have several sources of information available -- your extension service, other private or commercial applicators experienced in the same work and manufacturers. The manufacturer can usually furnish rather complete performance data and you should take full advantage of any charts, calibration aids or other help that he can supply.

COMPONENTS OF PESTICIDE APPLICATION EQUIPMENT

Your core manual describes the principal types of pesticide application equipment. This section will describe some of the parts that make up application equipment of importance for use in agriculture, forestry, nursery, ornamentals, and turf. Determine your needs, then check manufacturers specifications to obtain the right equipment for the right job.

Tanks

The tank is a major component of a sprayer. It should be large enough to avoid the need for too frequent refilling. (If your nozzle discharge is 10 gpm, a 100-gallon tank will last only 10 minutes. But, too large a tank is wasteful if it is seldom filled).

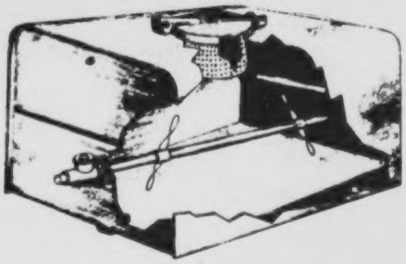
Stainless steel and fiberglass are considered the best tank materials because of their corrosion resistance, but they are expensive, so the buyer must weigh his need for durability against cost.

Every spray tank should have shut-off valves so that any liquid in the tank can be held there without leaking out of the pump, strainers, or other parts of the system which are serviced most frequently.

Agitators

The need for agitation depends on the type of chemicals applied. Liquid concentrates, soluble powders, and emulsions (i.e., 2,4-D, malathion EC) require little agitation -- usually the flow from the by-pass hose is enough.

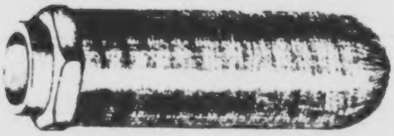
Wettable powder suspensions, however, require vigorous agitation to prevent settling out. Tanks with square corners require better agitation than tanks with rounded shapes.



There are two methods of agitating the spray material in the tank. Mechanical agitation, the most positive method, is provided by paddles or propeller. Hydraulic agitation is provided by the return flow of excess spray material from the pump. When hydraulic agitation is used to suspend wettable powders, a simple by-pass line from the relief valve is not enough. There should be a separate agitator line from the pressure side of the pump to the bottom of the tank.

Strainers

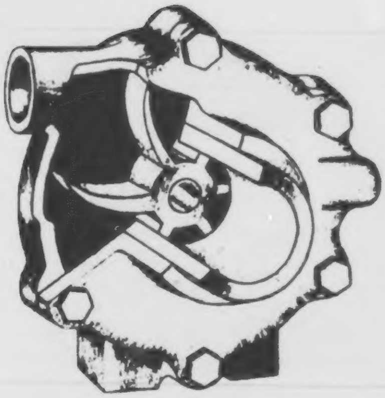
Strainers are used to prevent scale, rust flakes and other foreign material from plugging the nozzle or other working parts of your sprayer. They may be installed as necessary on the pressure line or may be purchased as a part of the nozzle and should also be placed on the intake line.



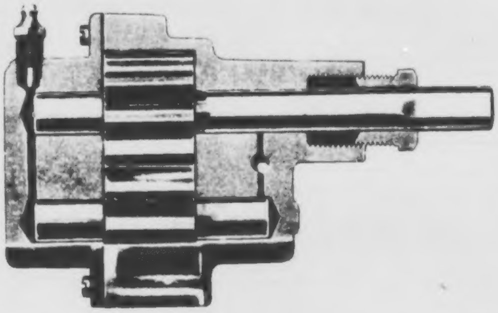
Pumps

A good spray pump must deliver the required pressure and the required volume within its normal working capacity so it is not constantly working at its limit. If abrasive materials are used it must be able to pump them over a long period of time without much loss of performance. The metal parts must be resistant to corrosion if corrosive materials are to be used. You must choose gaskets, plunger cups and impellers that are resistant to swelling or chemical breakdown when using most liquid pesticides. If wettable powders are used the pump must be abrasion resistant.

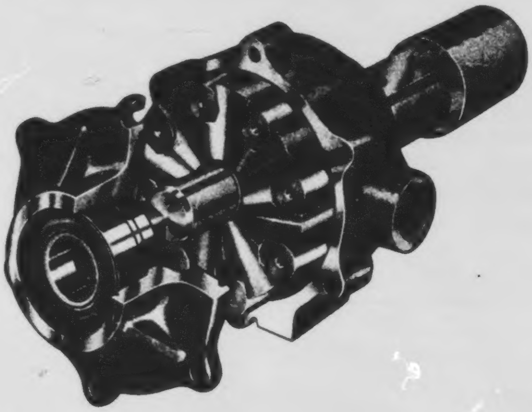
Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. The pump will usually take this stress for a short time, but will soon break down or wear out. Never run pumps dry since they depend on the spray liquid for lubrication. Some spraying applications require only simple economical pumps. Generally speaking, as your pressure and volume requirements increase, the cost and complexity of a satisfactory pump also increases.



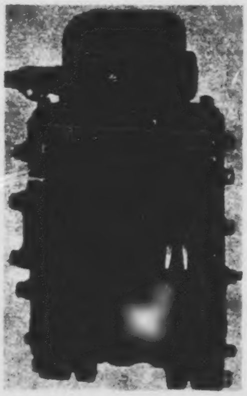
Centrifugal sprayer pumps use an impeller to give high volumes at low pressures, although two stage centrifugal pumps now used on some orchard and vegetable sprayers develop pressures in excess of 200 psi. The power requirement is relatively low and the operating speed is relatively high. They are the only sprayer pumps in general use that are not positive displacement pumps so pressure regulators or release valves are not essential. Pressure depends on RPM of the pumps. Because the impeller does not contact the pump housing, most centrifugal pumps are satisfactory for pumping abrasive mixtures such as wettable powder suspensions even when they are concentrated. Centrifugal pumps are not self priming so they must be mounted below the tank outlet or a priming system must be built in. They are relatively cheap, but are entirely satisfactory for many types of application.



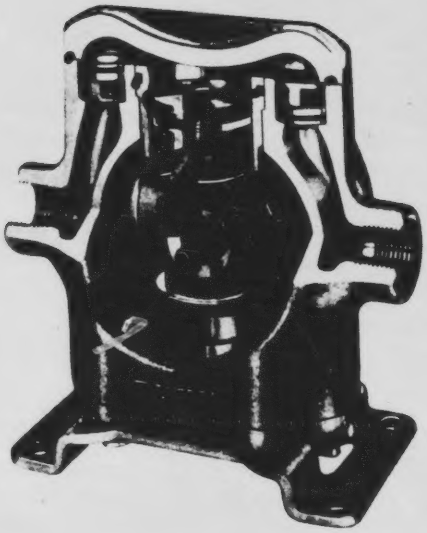
Gear pumps are simple, low priced positive displacement pumps that are used on agricultural sprayers for operating pressures of up to 100 pounds. They are satisfactory for pumping liquids or emulsions, but wear rapidly if suspensions are used. They are self priming when in good condition, but may lose that ability when worn. Depending on size, they deliver low to moderate volumes of liquid. They are not affected by solvents since all the parts are metal. Some are cast iron with stainless steel impellers; others are bronze so they will resist corrosion. They are commonly used on mist blowers and boom sprayers. Their power requirement is more than for centrifugal pumps, but is still relatively low. When a gear pump becomes worn it usually cannot be satisfactorily rebuilt.



Roller pumps are commonly used on low pressure and boom type sprayers. They are positive displacement self priming pumps with a slightly higher power requirement than gear pumps. They are also generally more costly but still relatively inexpensive. The rollers, made of nylon or rubber, are more abrasion resistant than the gears in gear pumps and can be replaced when worn or swollen. However, suspensions will wear the rest of the pump out after awhile. Roller pumps are capable of higher pressures than the gear pumps that are used on sprayers but sustained operation at maximum pressures will often cause the seals to blow out.

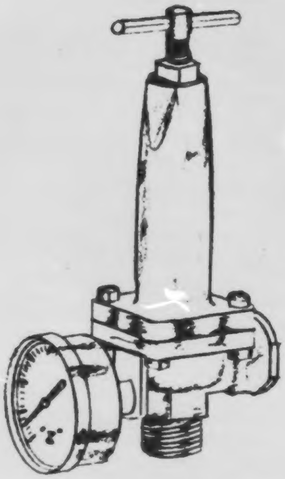


Diaphragm pumps are similar to gear and roller pumps in volume and pressure characteristics. Since the spray mixture does not come in contact with any moving metal parts except the valve assembly, these pumps are extremely abrasion resistant. The neoprene diaphragm may be injured by some solvents. Where volume or pressure requirements are not high these pumps are probably the best choice for abrasive spray suspensions.



Well made piston pumps are probably the most reliable of the commonly used sprayer pumps. They are heavily built and the larger ones are capable of pressures of 600 lbs/sq. in. or more. They deliver moderate to high volume depending on the pump capacity. The better quality pumps have replaceable plunger cups made of leather, neoprene or nylon fabric so they are abrasion resistant, easily rebuilt and capable of handling wettable powder suspensions year after year. The power requirement is higher than the other pumps. For low pressure sprayers a piston pump is not usually needed, but they are excellent where higher pressures are required or where both low and high pressures are needed.

Pressure Regulators



A pressure regulator is one of the most important parts of a sprayer. The pressure regulator controls the pressure and therefore the quantity of spray material delivered by the nozzles. It protects pump seals, hoses, and other sprayer parts from damage due to excessive pressure and by-passes the excess spray material back to the tank.

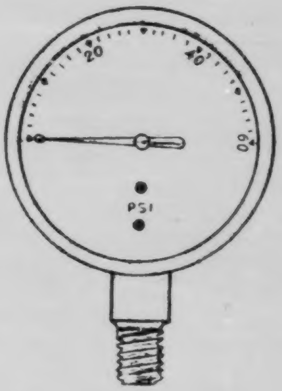
There are two types of pressure regulators, simple relief valves and pressure unloaders. The relief valves are simple by-pass valves that require the pump and engine to keep working just as though one were spraying, whereas the unloaders maintain working pressure on the discharge end of the system but move the overflow back into the tank at lower pressure, thus reducing strain on the engine and pump.

In the past almost all high pressure hydraulic sprayers were equipped with unloaders, but now, probably as an economy move, the trend is toward relief valves. There is no substitute for a spring-loaded pressure regulator.

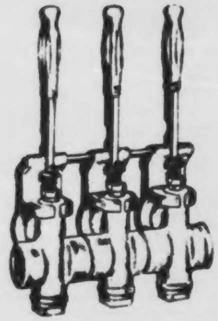
When selecting a pressure regulator, be certain that the flow capacity of the regulator matches that of the pump being used.

Pressure Gauge

A pressure gauge is essential on any sprayer. Without one, the operator cannot tell how the sprayer is functioning. If the pressure does not remain constant, the amount of liquid coming out of the nozzles will vary. The gauge should always be mounted so that the operator can see it easily. Pressure gauges often wear out soon because they become clogged with solid particles of spray material. A glycerine loaded diaphragm type gauge is more expensive, but will last indefinitely.

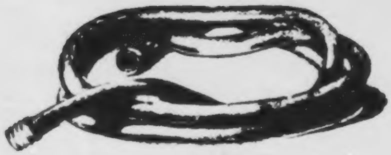


Selector and Shut-Off Valves



The selector and shut-off valve allows the operator to conveniently select one to three sections of the boom for spraying a narrow strip in the field, or to shut off all sections of the boom quickly and easily at the end of the field.

Hoses



There are four main points to consider in selecting sprayer hoses:

1) Composition (chief liner material)
2) Construction (reinforcement, rigidity or flexibility)
3) Working pressure
4) Size

High quality hoses and fittings are expensive but economical when used over a long period of time. The hose liner should be resistant to chemical action of the spray materials. The working pressure of the hose should be equal to the maximum pressure the pump delivers. If the hose is too small (inside diameter) the sprayer will not operate properly. If the hose in the suction line is too small the pump will starve. If the hose in the pressure line is too small there will be excessive pressure and drop in volume.

PESTICIDE EQUIPMENT

Depending on the crop being grown the following are examples of specific equipment for proper pest control. You will be responsible for knowledge of the equipment that is commonly used in your commercial category or subcategory.

Agricultural

1) Plant

    Multipurpose sprayers

    -- Low and high pressure boom sprayers

        .. low - field and forage, vegetable

        .. high - vegetables, small fruit

    -- High pressure sprayers (hand gun and hose)

        .. Tree fruit, brush control, Christmas trees

    Airblast

        .. Tree fruit, small fruit, vineyard, vegetable, Christmas trees

    Granular

        .. Vegetables, small fruit, field crops, Christmas trees

    Soil fumigation

        .. Tree fruit, small fruit, vegetables

    Aerial

        .. Vegetables, tree fruit, small fruit, field and forage, vineyards, Christmas trees

Forestry

Aerial
- .. Forests

Mist blower
- .. Forest nurseries, seed production area, forests

High pressure (hydraulic) sprayer
- .. Forest nurseries, seed production areas

Low pressure (boom) sprayer
- .. Forest nurseries

Soil Injectors
- .. Forests, seed production areas

Granular
- .. Forest nurseries, seed production areas

- Soil Fumigation
  - .. Forest nurseries

Ornamentals and Turf

1) Arborist
   - High pressure (hydraulic) sprayer
   - Mist blower (airblast)
   - Injectors
2) Landscapers
   - Multipurpose sprayers
   - -- High pressure sprayers (hand gun and hose)
     - .. Trees, shrubs, vines, turfgrass
     - .. Vines and turfgrass
   - Mist Blowers
     - .. Trees, shrubs, vines
   - Granulars
     - .. Trees, shrubs, turfgrass
   - Soil Fumigation
     - .. Turfgrass
   - Injector
     - .. Trees
3) Nurserymen
   - Multipurpose sprayers
   - -- High pressure sprayers (hand gun and hose)
     - .. Propagation house
     - .. Nursery blocks and fields
   - Mist blower
     - .. Propagation house
     - .. Nursery seedling beds
     - .. Nursery blocks and fields
   - Granular
     - .. Nursery seedling beds
     - .. Nursery blocks and field
   - Soil Fumigation
     - .. Nursery seedling bed
   - Aerial
     - .. Nursery field

4) Turf Managers
  Multipurpose Sprayers
  -- Low and high pressure boom sprayers
    .. Low - golf course fairways, other turfgrass areas
    .. High - golf course fairways, other turfgrass areas
  -- High pressure sprayers (hand gun and hose)
    .. Trees, shrubs, greens, lawns (school grounds, parks, industrial grounds, etc.)
  Aerial
    .. Golf course fairways, parks
  Granular
    .. Golf course fairways and greens, lawns (school grounds, parks, industrial grounds, etc.)
  Soil Fumigation
    .. Golf course greens

****

Multipurpose Sprayers

Agricultural (plant), Ornamentals and Turf, (Arborists, Landscapers, Nurserymen and Turf Managers) Forestry (Forest Nurseries and Seed Production Areas)

Multipurpose sprayers are designed to handle most spraying needs from low-pressure weed or row-crop spraying (30 to 50 pounds) up to higher pressure fruit tree and field-crop spraying (200 to 400 pounds or more).

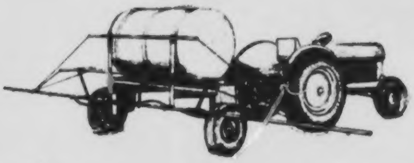
The sprayers have plunger- or piston-type pumps that deliver 3 to 8 gallons per minute at pressures up to 800 pounds. Tanks range in size from 50 to 800 gallons. The spray material is mechanically agitated.

Skid-mounted models are powered by an auxiliary engine. Wheel-mounted models may be powered by an auxiliary engine or by the tractor's power take-off.

Hand gun and hose are standard equipment; field booms, usually 20 to 35 feet in length, are available as optional equipment.

Boom Sprayers-Low Pressure and High Pressure

Agricultural (plant), Ornamentals and Turf, Forestry (Nurseries)



Sprayer booms are commercially available in lengths of 15 to 60 feet. The most common boom length is between 20 and 35 feet. Even with a 20-foot boom, it is essential to have some means of protecting the boom from damage if a tree or other obstacle is encountered. The most common boom is made in three sections -- one rigid section in the middle of the machine and a folding section extending out on each side. These outer sections are hinged at their inner ends and are supported from the center of the machine by a rope or light chain. This type of construction gives a 20- to 35-foot boom adequate support, and provides the versatility necessary in irregularly shaped areas and the mobility required when moving the sprayer through narrow gateways.

The height of the sprayer boom must be easily adjustable so the nozzles can deliver the chemical uniformly. Boom supports should be made so the boom can be set at any height from 12 to 48 inches above the surface being sprayed.

Your core manual describes low pressure field sprayers and high pressure (hydraulic) sprayers. While they differ somewhat in performance characteristics, both are used as agricultural and turf boom sprayers. The methods for calibration apply to both types of sprayer.

Boomless sprayers have a central nozzle or nozzles that are designed to produce a very wide spray pattern resulting in a wide swath similar to that laid down by a boom type sprayer. They may be calibrated by spraying a known acreage with water and refilling as described in your core manual.

There are four variables that you can adjust to govern the amount of spray delivered by boom sprayers. These are:

- nozzle spacing on the boom
- nozzle tip orifice size
- pressure
- ground speed of the sprayer

Usually your equipment will already be set up to meet your local needs, so you will make minor changes in spray delivery by changing the speed and/or pressure, and major changes by using larger or smaller nozzle tips. Routine checks of your sprayer should be made to make sure that the nozzles are not badly worn and have uniform output, uniform appearance of spray pattern and equal fan angle. Replace any nozzle tips having a flow of 10% more or less than required or having obviously different fan angles or patterns.

Nozzle Bodies

A complete nozzle assembly consists of the body, screen, cap, and tip or orifice plate. The function of the nozzle body is to attach the screen and tip to the boom. Several different nozzle body designs are available. All designs perform adequately, but each design has advantages for specific spraying jobs.

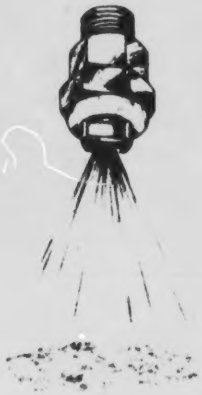
Nozzle Tips

A nozzle is an atomizing device that spreads the liquid droplets in a definite direction to form the spray pattern. Nozzles are made to accommodate a variety of replaceable tips or discs to meet different spraying requirements. Manufacturers of sprayer nozzles can supply data sheets for the delivery rate (usually in gal/min at different pressures for their nozzles). The application rate CANNOT be specified on these data sheets unless the forward speed of the sprayer and the spraying pressure are specified.

WARNING -- Never operate nozzles at high pressures to compensate for selecting the wrong nozzle size. Unnecessarily high pressures increase the rate of nozzle wear and increase the drift hazard.

Nozzle tips and discs are made of aluminum, brass, ceramic, plastic, stainless steel, or tungsten carbide. Tungsten carbide discs and stainless steel tips are more resistant to abrasive wettable powders, but they are more expensive than steel discs and brass tips. No single material is the least expensive, most corrosion resistant, and most durable for spraying all agricultural chemicals.

Nozzles are classified according to the spray pattern as (1) fan or flat pattern, (2) broadcast or boomless, (3) flooding fan, and (4) full cone or hollow cone.



The regular flat fan nozzle makes a narrow oval pattern with lighter edges. It is used for broadcast spraying. This pattern is designed to be used on a boom and to be overlapped 30-50 percent for even distribution.

Flat Fan—There are three types of flat fan nozzles:

Fan or Flat Pattern Nozzles

The spray droplets are arranged in a fan shape as they leave the nozzle. The orifice (opening) in this type of nozzle is elliptical. Herbicides are best applied with this type of nozzle because:

1) when a series of these nozzles is properly mounted on a boom, the spray material is more evenly distributed than it would be with any other type of nozzle; and
2) at 30 to 60 psi, the flat-pattern nozzle delivers small to medium droplets that do not drift excessively.

The most commonly used flat-pattern nozzles have a spray angle of 65, 73, or 80 degrees; the most commonly used pressure is 40 psi.

For most herbicide spraying done with a relatively short boom (20 to 35 feet), the 80-degree flat-pattern nozzle is best. It is possible to keep the boom relatively low to reduce the drift hazard, and give a uniform distribution of spray material over the entire length of the boom.

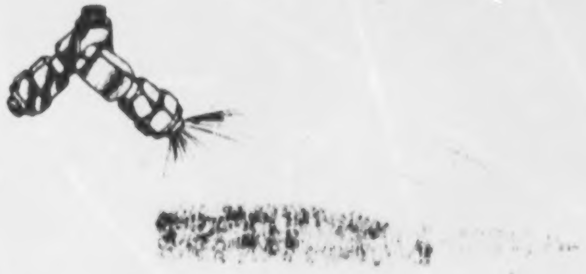
Special flat-pattern nozzles, usually called even-spray nozzles, are available for band spraying row crops. If a uniform distribution of herbicides is required, these nozzles should not be used.

The flat-pattern nozzle is available in brass, plastic, stainless steel, and hardened stainless steel. The brass nozzle is inexpensive and satisfactory for spraying chemicals in solution. It is not durable enough to spray any more than 20 acres with atrazine. The plastic nozzle is corrosion resistant but should not be used to spray more than 60 acres with atrazine. The stainless steel nozzle is corrosion resistant and durable but should not be used if more than 200 acres are sprayed with atrazine. The hardened stainless steel nozzle is the most durable, but it is not as corrosion resistant.

NOTE -- When using any wettable powders, it is essential to calibrate the sprayer frequently, because as a nozzle wears, the quantity of spray material delivered INCREASES.

Broadcast or Boomless Nozzle

The broadcast nozzle is made of one or more nozzles in a cluster. These nozzles deliver a flat fan-like pattern that covers a swath up to 70 feet wide. The spray droplets range in size from very small to very large. Broadcast nozzles are convenient for spraying areas in which a uniform distribution of spray material is not essential.

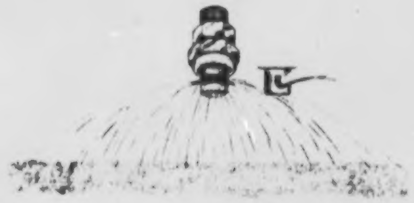


Broadcast—This nozzle forms a wide flat fan pattern. It is used on boomless sprayers and to extend the effective swath width when attached to the end of a boom.

CAUTION: Never use a broadcast type of nozzle when there is any breeze. Severe drifting and crop damage may result.

Flooding fan

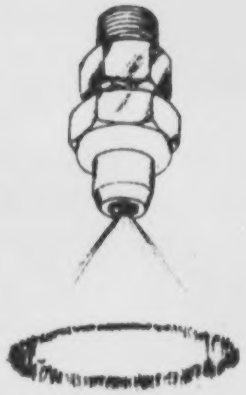
This is a broadcast-type nozzle that has been modified to be mounted on a boom. The nozzle spacing usually used is 40 to 80 inches. The small- to large-sized spray droplets are not distributed as uniformly as the droplets from a flat-pattern nozzle. The flooding-fan nozzle is available in brass or stainless steel. Its main use is for surface application of herbicides that are immediately incorporated into the soil.



The flooding nozzle makes a wide-angle flat spray pattern. It works at lower pressures than the other flat fan nozzles. Its pattern is fairly uniform across its width. It is used for broadcast spraying.

Full Cone or Hollow Cone

These two types of nozzles deliver circular patterns. The hollow-cone nozzle delivers most of the material to the circumference of the circle; the full-cone nozzle delivers liquid droplets to the entire area of the circle. The circular opening in the stainless steel, hardened stainless steel, or tungsten carbide disc



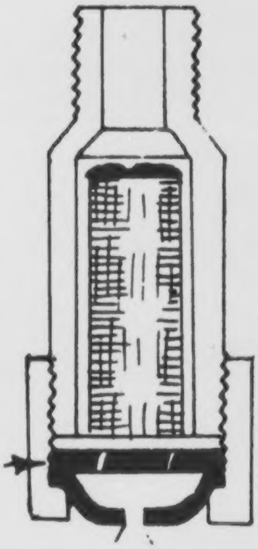
Hollow Cone—There are two types of hollow cone nozzles:

- the core and disk, and
- the whirl chamber.

The pattern is circular with tapered edges and little or no spray in the center. It is used for spraying foliage.

resists the abrasive action of wettable powders relatively well. The droplets are small or very small and not distributed uniformly when the nozzles are mounted on a boom. The major use of these nozzles is in the application of insecticides or fungicides to field crops where complete coverage of the leaf surfaces is extremely important and where spray drift is relatively unimportant. In cone nozzles the number of holes in the whirl plate affects the discharge rate. Be sure to check the whirl plate as well as the nozzle tips in calibrating a sprayer.

Nozzle Screens



The screen is placed behind the nozzle tip and in the nozzle body to help eliminate, or at least reduce, the frequency with which the nozzle orifice becomes plugged. The size of the nozzle opening and/or the type of chemical being sprayed dictate the size and type of nozzle screen that should be used. For most general herbicide spraying, a 100-mesh monel or stainless steel nozzle screen can be used. When wettable powder suspensions are being applied, a 50-mesh monel or stainless steel nozzle screen should be used.

When the boom must be turned off frequently -- in small fields or when the crop may be damaged by an overdose of chemical -- nozzle "dribble" may be a serious problem. A nozzle screen with a check valve in it will help eliminate dribble and will not affect the operation of the sprayer. Some care must be taken to make certain that the ball bearing does not become glued to its seat or that dirt or chemical particles do not hold the ball bearing off its seat.

Calibration of Boom Sprayers

There are several ways to calibrate boom type field sprayers. Your core manual gives you the method that is probably the simplest, but it also takes time because it requires spraying a measured acre with water. Another method involves timing the discharge rate of the sprayer over part of an acre and doing simple calculations. Neither of these methods cause variation in flow across the boom to be considered or corrected. Calibration jars that indicate rates of application over a given distance may be purchased.

High Pressure Sprayers (Hydraulic), Hand Gun and Hose

Agricultural (Plant), Forestry, Ornamental and Turf (Arborist, Landscapers, Nurserymen, and Turf Managers)

These machines are commonly used in turf, ornamental and shade tree spraying as well as for orchards and as boom sprayers for heavily foliaged vegetable crops. Usually they have piston pumps and mechanical agitators and are solidly built, long-lasting machines.

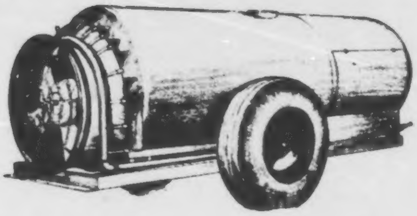
Usually high pressure hose and a hand-held spray gun are used when treating foundation plantings and other ornamentals, shade trees or nursery blocks, but a spray boom may be used when applying turf insecticides or fungicides.

Foundation plantings, nurseries and turf can be treated with hydraulic sprayers of moderate pumping capacity such as 6 to 10 gpm at 400 - 500 psi.

Tall shade trees require high pressure, high volume pumps capable of 35 - 60 gpm at 650 psi. Spray mixtures used for ornamentals and shade trees are dilute, either suspensions or emulsions and the proper concentration of spray as mixed in the tank is applied to the point of runoff. Consequently, the sprayer does not have to be calibrated as long as it is big enough to adequately cover the target. When a boom is used for treating turf, the sprayer can be calibrated according to methods given in your core manual.

Airblast Sprayers

Agricultural (Plant), Forestry (Seed Production Areas)



Airblast sprayers are now in general use for treating tree fruits and are increasing in use for the spraying of row and field crops. (Mist blowers, a type of airblast sprayer, are used on shade trees and ornamentals.) They may be used to apply sprays ranging from dilute to highly concentrated. All use air to transport pesticides to the crop. Most use nozzles under pressure to provide initial breakup of the liquid, but some rely on airblast to shear the liquid into fine droplets. The volume and velocity of the airstream and the shape and arrangement of the air outlets vary depending on the purpose for which the machine was designed. It is essential that the airblast be sufficient to distribute the spray droplets throughout the swath to be covered.

Airblast machines for treating fruit trees are classified as follows:

1. Dilute spray (high gallonage) 301 or more gallons per acre.
2. Semi-concentrate (moderate gallonage) 101 to 300 gallons per acre.
3. Concentrate (low gallonage) 20 to 100 gallons per acre.
4. High concentrate (very low gallonage) 1 to 19 gallons per acre.

*5. Ultra high concentrate (ultra low volume) less than 1 gallon per acre.

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*Not satisfactory for treating fruit crops at present.

Many machines may be modified to make applications in more than one classification. However, because of airblast and pump limitations, machines designed for low volume usually cannot be used for applying dilute sprays. Likewise, high volume machines are not efficient for use in applying low volume since the airblast and pump capacities would be excessive.

The principles for adjusting and calibrating airblast machines for treating fruit trees are the same regardless of the volume of water to be used.

Calibration Procedures (Trees)

1. Make sure that the fan and pump are operating at speed indicated in the operator's manual and that all strainers, nozzles and similar equipment are clean and in good condition.
2. Check the liquid pressure at the nozzle position on the discharge manifold. Pressures must be within limits set in your operator's manual and/or nozzle performance table.
3. Determine the effective airblast. Effective airblast is that part of the airblast actually used in covering the trees in question.
4. Make a diagram of the air outlet and liquid manifold. Indicate the effective airblast, nozzle positions and upper one-third of effective airblast.

5. Determine:
   a. Gallons per acre to be applied
   b. Distance between rows
   c. Speed at which the sprayer is to be operated
6. Use a calibration slide rule provided by the manufacturer or the formula given below to calculate gallons to be discharged from one side of the machine.

   Gal/min (per side) =

   $$\frac{\text{gals/acre X miles per hour (mph) X distance between rows (ft)}}{1000}$$

   For example, if one selects 200 gals/acre and 2 mph in an orchard with 25 ft. row spacing:

   $$10 \text{ gals/min} = \frac{200 \text{ X } 2 \text{ X } 25}{1000}$$

7. Divide gals/min per side by 3. In the case cited above this would mean 10 ÷ 3 = 3.33. Two-thirds of this volume or 6.7 gals. should be discharged through the upper 1/3 of the effective airblast and 1/3 of the volume or 3.3 gallons should be discharged through the lower two-thirds.

   Now consult a manufacturer's chart which matches the nozzles and nozzle pressure which you are using and select the appropriate sizes to give the desired rate of delivery for each position on the manifold. Spray coverage will be more satisfactory if nozzle sizes are selected which will give a gradual decrease in volume from the top to the bottom of the effective airblast, still maintaining the pattern of 2/3 of the liquid being discharged in the upper 1/3 of the airstream.
8. Install the desired nozzles in their appropriate positions. Unused nozzle positions above the effective airblast should be shut off but may be fitted with intermediate size nozzles for use during poor spraying conditions or for covering trees larger than those for which the sprayer was calibrated.

9. Fill the tank at least 1/4 full. Turn on the newly nozzled side and check the time it takes to empty the tank. Calculate the gallons discharged per minute. The example given in Step 6 indicated 10 gallons per minute as the desired delivery rate. At this rate the tank should empty in 5 minutes if 1/4 full is 50 gallons. Your allowable error should not be greater than 5% or 15 seconds. This means that a range from 4 minutes, 45 seconds to 5 minutes and 15 seconds is within desired limits. If the delivery rate falls within this range, nozzle up the other side and go to work. If not, go back over your calculations to find the error. If there is no error in your calculations the problem may be a faulty pressure gauge, wrong nozzle size, or obstructions that may have developed in strainers or other parts of the liquid system.

Most of the effort to calibrate and adjust a sprayer is lost unless it is operated at the right speed. Travel speed may be checked with a special speedometer, an engine tachometer (if proper adjustment is made for tire slippage) or by finding the number of trees you should pass per minute at the desired mph. Use the formula:

$$\text{trees passed/min} = \frac{\text{mph} \times 88^{*}}{\text{tree spacing in feet}}$$

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*1 mph - 88 feet per minute

If your trees are planted 25 feet apart and you plan to travel at 2 mph, then using the above formula you should spray 7 trees per minute.

$$7 \text{ trees/min} = \frac{2 \times 88}{25}$$

If you are spraying more than 7 you are traveling too fast; less than 7, too slow. Adjust your speed accordingly.

After the newly calibrated sprayer is operating satisfactorily periodic maintenance checks should be made to assure continued high performance. This should include checking the engine or PTO rpm, wear on the nozzles, strainers, pressure, and possible partial clogging of pipes and/or the hose lines and nozzles.

Calibration (Row Crops)

Airblast sprayers for treating row and field crops should be calibrated using the same general procedure followed for those used to treat fruit trees. Slight variations in the procedure are as follows:

1. The swath width in row crop spraying is the distance between passes made across the field. The formula to calculate gallons to be discharged from one side of the machine then becomes:

$$\text{gals/min} = \frac{\text{gals/acre X mph X swath width in feet}}{500}$$

2. The most effective liquid discharge pattern within the airstream varies from one machine to another. In most cases it is necessary to discharge a large part of the liquid in the upper part of the airstream to assure proper deposits at the more distant parts of the swath. See manufacturer's operation manual for suggested nozzle sizes and arrangement.

3. You can check your speed by measuring the distance your sprayer travels in one minute and dividing by 88 (feet per minute traveled at one mph). Suppose you travel 176 feet in one minute:

$$2 \text{ mph} = 176 \div 88$$

Mist Blowers

Forestry, Ornamental and Turf (Arborist, Landscapers, Nurserymen, Turf Managers)

Mistblowers are airblast sprayers that are economical and effective for use against many pests of ornamentals and shade trees. They vary in size from small back pack blowers which are powered by 2 cycle engines that move a few hundred cubic feet of air per minute (cfm) at velocities up to 200 mph to large truck or trailer mounted machines that move up to 60,000 cfm at velocities near 100 mph. They may have single or multiple nozzles that inject the pesticide into a single air outlet. Usually the back pack models depend on the shearing effect of the airblast to break the pesticide into fine, mist-like droplets. Larger mist blowers may pump liquid under varying pressures through nozzles to initiate breakup, but these models also depend on the airblast for final breakup into fine droplets.

Since mistblowers are dependent on a column of air to carry the pesticide to the tops of tall shade trees they must be operated in little or no wind. Under good conditions there is no difficulty in reaching the tops of the tallest tree. However, operations should cease when the wind exceeds 4 - 5 mph. Otherwise, not only will it be difficult to reach tree tops, but excessive drift of pesticide will also result.

Emulsions are commonly used in mistblowers although wettable powders can be used. Some pesticides are available only as wettable powders or flowables. Usually relatively high concentrations of pesticides are used in mistblowers; a rule of thumb being 30 X dilute concentrations. One or two quarts of concentrate is often sufficient for a large tree. The insect pests best controlled by mistblowers are those that move to some degree, i.e., cankerworms and other worms and caterpillars, leaf beetles, lace bugs, etc. Pests such as mites, scales and fungi can be controlled but it is advisable to lower the concentration and increase the gallonage per tree accordingly.

Mistblowers while designed primarily to apply insecticides and/or fungicides, can also be used to apply herbicides in timber production areas -- for control of brush under conifer stands or for selective brush control in regenerating stands. In these cases the standing trees restrict air movement and thus help control drift. When using an airblast sprayer for herbicide application in forests do everything possible to reduce drift such as:

- Work on a calm day (less than 5 mph wind).
- Apply herbicides only in timber production areas.
- Follow local regulations regarding distance from crops.
- Use operating pressure less than 20 psi.
- Use largest practical nozzle openings.
- Do not spray near sensitive areas.

Mistblowers are advantageous over hydraulic sprayers in that they are lighter in weight, use far less water and are physically easier to operate.

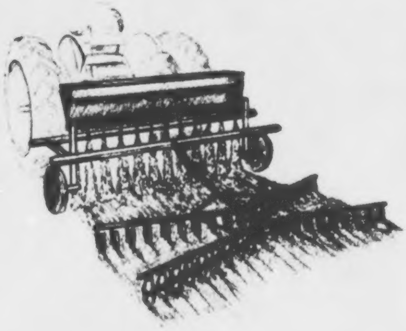
Calibration

Mistblowers must be calibrated before using on ornamentals and shade trees. You do not apply pesticides in high concentration to the point of runoff as you do with hydraulic sprayers. In fact, it is difficult to see the usual mistblower deposit. Consequently, it is very easy to overdose. You must know the amount per minute of pesticide that your blower is delivering to the target and then time your application so that the right amount of spray concentrate is applied. Larger mistblowers are normally nozzled to deliver 1/2 to 2 gallons per minute (gpm). Thus, if a tree requires 2 quarts of 3% carbaryl spray and your blower delivers one gpm, you should treat the tree in 30 seconds. Your core manual tells you how to determine pumping rate, or as it is more properly called, delivery rate.

Sometimes it is necessary to apply a specified amount of pesticide per acre with a mistblower, for instance in treating nursery blocks or golf course fairways and greens. You can use the same procedure for calibration as is described for row crop calibration of airblast equipment.

Granular Application

Agricultural (Plant), Ornamentals and Turf (Landscapers, Nurserymen, Turf Managers), Forestry (Forest Nurseries and Seed Production Areas)



Granular pesticides must be applied with precision. Application of less than 90% of the label rate may result in ineffective control. Applications greater than recommended are costly and may be injurious to the crop. To meet these rigid requirements, spreaders must be carefully calibrated.

The amount of granules applied depends on the size of the metering opening, speed of travel, roughness of the field, and the flow rate of the granules. Granules flow at different rates, depending on size, density, and type of granule, temperature and humidity. Therefore, it is necessary to recalibrate your applicator for each different formulation.

Broadcast Applicators

These applicators may be of the full width hopper type with sliding gate openings or augers, or those using air, or spinning disks to cover swaths much wider than the machines.

With the full width sliding gate and auger types one should check the evenness of distribution from all the openings by setting the gate at a particular opening, turning the drive mechanism and comparing the output over a given time from each opening. Use the actual pesticide to be applied and a preliminary setting as recommended by the equipment operator's manual for the pounds per acre desired.

For the air and spinning disk types, select a preliminary setting as recommended by the operator's manual for the application rate desired. Select and determine your actual travel speed, then check the distribution pattern in the field. Containers deep enough to keep the granules from bouncing out should be placed on two foot centers across the swath at several intervals along the first pass. Then visually, volumetrically, or by weight compare the output at each station. This will alert you to any correction needed and allow you to select the best swath width.

To check the application rate, fill the hopper, settle the material in the hopper, then refill. Treat a known acreage using at least 10% of hopper contents and determine the pounds of granules required to refill. Then:

$$\text{pounds per acre} = \frac{\text{amount used (in pounds)}}{\text{acres covered}}$$

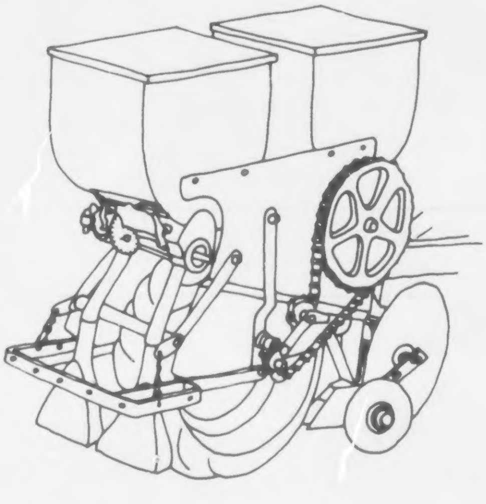
If the pounds per acre used is within 10% of that desired, treat another acreage and recheck the delivery rate, then make minor adjustments to correct the rate to within 5% and keep the delivery rate frequently rechecked during application.

If the amount used is more than 10% in error, then change the applicator's rate settings and recalibrate. Keep calibrating until the rate is correct to within 5%.

Remember most units require that speed be held almost constant to keep the application rate constant. Also weather conditions can markedly affect granular flow rates so be alert to such changes.

Band or Row Applicators

These applicators should have tubes to the spreader which are not too long nor too shallow. Some use a flexible metal hose to carry granules from the hopper to the ground. The hose must not be too long for even flow or the application rate will vary along



the row. Careful adjustment of the hose position or length may be necessary to provide uniform flow.

Banders should spread the band evenly even when on 10 to 15% slopes. Chain drives should use sprockets of 8 teeth or more to keep the drive speed uniform. Design should be such that the flow of granules stops when the drive stops even when the outlets remain open. The drive should be strong enough to turn and not break when restarted after road travel even when the hopper is full of granules.

Care must be taken to insure the placement of the granules over the row or in the row as the pesticide label directs. Proper placement in some cases is as important as proper calibration.

Band applicators should be calibrated in the field just like broadcast granular applicators, after first calibrating in a manner similar to row or directed sprayers (outlined below).

Step 1. Set each individual applicator to apply the desired amount per acre as suggested in the equipment operator's manual.

Step 2. Fill hoppers at least half full, turn on applicators and run until all begin feeding.

Step 3. Disconnect nozzle of spreader and attach container under each tube.

Step 4. Travel a measured distance (at least 1/8 mile or 660 feet) at the speed you wish to apply in the field.

Step 5. Weigh the amount recovered for each band separately and record. Use an accurate scale such as a postal or kitchen scale.

Step 6. Calculate the application rate for each unit using Equations 1 and 2 where the band width (in feet) is the swath width.

Equation 1:

$$\text{acres covered} = \frac{\text{Distance traveled (ft) X swath width (ft)}}{\text{43560 (sq ft/acre)}}$$

Equation 2:

$$\text{application rate (lbs acre)} = \frac{\text{amount used (lbs)}}{\text{acres covered}}$$

- -- This is the broadcast rate per acre and the rate the pest is subjected to in the banded area. The amount used per crop acre will be reduced by the ratio of band width to distance between rows.

- -- For some pesticides such as soil insecticides the recommended rate is in lbs. per crop acre in which case use row spacing (in feet) for swath width in Equation 1 and your answer will be in lbs. per crop acre directly.

- -- If the recommendation is in lbs. per 1000 ft. of row, then:

$$\text{lbs/1000 ft. of row} = \frac{\text{lbs. collected X 1000 ft.}}{\text{distance traveled (ft.)}}$$

Step 7. If the delivery rate isn't within 5% of that recommended on any unit, adjust it accordingly and repeat Steps 3 - 6 until it falls within the 5%.

Step 8. Use the method described for broadcast application during the first part of each application to check the delivery rate. Adjust the settings accordingly.

Soil Fumigation Application

Agricultural (Plant), Ornamental and Turf
(Landscapers, Nurserymen, Turf Managers), Forestry (Nurseries)

Equipment used for applying liquids or fumigants to the soil varies considerably, but all use one of two basic methods of metering out the liquid fumigant. The method of metering does not affect the efficiency of the material. Preferences of metering equipment are usually based on cost, simplicity, accuracy, practicality and the specific needs of the applicator. The two methods of metering are:

1. Orifice (opening) size is selected to restrict flow from a system which maintains constant pressure at the orifice. Constant speed is necessary to maintain uniform application rates. Pressure regulation varies with the equipment but is usually one of three types.

a. Constant head gravity flow. These units utilize a closed drum or tank with a special breather to establish a constant head of about 1/2 to 1/4 psi, dependent upon height differences between breather inlets to tank and the vented orifice. Needle valves, orifice plates and capillary coils are used to control flow rate. Capillary coils can vary in both length and diameter, but for any one application must be all the same length and diameter for equal pressure and delivery at the outlet.

b. Pump and pressure regulator. Gear, roller, diaphragm or similar pump units utilize either a power take-off or other power source. They generally operate at low to moderate pressures (5 - 20 psi).

c. Gas pressure. This method generally is used with highly volatile fumigants such as methyl bromide. Pressure approved storage tanks and pressurized nitrogen cylinders are used and a constant pressure in the fumigant tank is maintained with one of a variety of pressure regulation devices operating at 5 to 35 psi depending on the fumigant and metering system used.

2. Metering pumps are driven from a ground wheel and are geared to the pump. Full output of the pump or pumps is forced out of the orifices. Changes in output are adjusted by changing the gear ratios and/or the length of the pump stroke. Uniform output is independent of tractor speed. Piston pumps are most common but gear, roller, diaphragm or similar pumps can be used.

Some of the principal methods used for soil treatment are:

1. Injection systems. These are used for fumigants but can be used for other liquid soil pesticides.

   a. Chisel cultivators, blades, or shanks with volatile materials may be 8 inches or more apart; with non-volatile materials, banding or 1 to 2 inch spacing between chisels is necessary.

   b. Sweep-type cultivator shovels.

   c. Planter shoe.

   d. Plow.

   e. Transplant water.

2. Surface treatment/soil incorporation. This method is used mostly for low or non-volatile materials. Mixing is usually shallow, 5 inches or less. The simplest method is to spray soil, turn it in with disks and compact with a drag, float or cultipacker. Rotary hoes or weeders are also used. Non-volatiles are sometimes applied as granules.

3. Drenching and flooding. These methods are usually used prior to planting, but material may also be applied by irrigation water.

Calibration

This equipment can all be calibrated in the same manner as boom broadcast and band sprayers (See Core Manual). However, fumigant labels usually specify the desired flow rate as fluid ounces per 100 or 1000 feet of travel, or as feet traveled per pint of fumigant. A simpler technique is described below:

1. Establish the speed to be used in application by setting equipment at depth to be used, and then, leaving fumigant valves turned off, drive across a tilled field at a rate that allows a constant travel speed. This speed is determined in feet per minute and converted to feet per second by dividing by 60. If the tractor has a speedometer, its speed per second can be calculated by multiplying miles per hour by 1.45.

2. Determine collecting time:

$$\text{collecting time (seconds)} = \frac{\text{distance suggested on label}}{\text{speed in feet/second}}$$

   For example, if the label lists "X" ounces to apply per 1000 ft and speed is 8 ft/second, then:

$$\frac{1000}{8} = 125 \text{ seconds necessary to apply "X" ounces}$$

3. With the orifice pressurized and constant speed units, keep the unit stationary and with pump or pressure system operating at some preliminary setting:

   a. Collect the output for the collection time calculated above (Step 2).

   b. If the amount is more than 5% above or below the ounces per 100 or 1000 ft recommended on the label, change the pressure or orifices until the right amount is collected.

There are tables available that approximate the output for each fumigant over a range of pressures and orifice sizes.

4. With ground-wheel driven metering pump units:

   a. Determine the circumference in feet of the tire on the ground driven wheel.

   b. Divide the calibration distance by the circumference to obtain the number of turns needed for that distance.

   c. Turn the wheel the calculated number of turns while collecting the output from one or more of the outlets. If the amount is not right, change the gears or sprockets in the drive or change the length of the piston stroke and then recheck the delivery until it is within 5% of the amount recommended on the label.

5. Once field application is started, check the application rate immediately and often thereafter by comparing the amount used and the acreage covered.

   NOTE: Row treatment rates and calibration can be kept less confusing by remembering that flow rates per outlet are usually the same as for broadcast fumigation.

Tarpaulin Fumigation

When odorized methyl bromide (98% methyl bromide, 2% chloropicrin) is used, the area to be treated is generally covered with polyethylene sheeting (tarp). The tarp should be supported off the ground (not flat on the ground) to permit free movement of the gas under the tarp. The tarp should be sealed by laying the edges of the tarp in a small trench or furrow and covering 6 - 10 inches with soil. Care should be taken not to move any of this untreated soil onto the treated area when removing the tarp.

The fumigant can be introduced into evaporation trays using 1 pound for each 100 square feet of area to be treated, and adding the recommended amount of fumigant to each tray. Methyl bromide with 2% chloropicrin added as a warning agent (odorized) is available in small metal pressure cans (1 or 1-1/2 pounds). Also available are applicators with openers each with polyethylene tubing attached to introduce the liquid into the evaporation trays under the tarp. For larger jobs, large cylinders may be used with application tubing attached and utilized in a similar manner to that above. The amount of odorized methyl bromide applied can be measured by placing the cylinder on a scale and measuring loss of weight, or using a special cylinder-metering device attached to the cylinder. In either case, the amount required per evaporating tray is metered out and generally introduced into numerous evaporation trays.

Tarped fumigants can also be injected by tractor-drawn chisel applicators. Commercially, overall tarping is the most efficient and common practice. A tarp layer is mounted behind the chisel applicator. In laying the tarp, one edge of the tarp is buried with bedding disks and the other edge glued to the adjacent laid strip of tarp, with the first strip having both edges buried. Fumigant injection and tarp laying proceeds until the entire field is covered with overlapping strips of polyethylene tarp.

Another less efficient and more time-consuming method is to treat alternate strips of equal width, burying both edges of the tarp. After 1 - 2 days' exposure, the tarps are removed by splitting down the middle, removing each half toward corresponding edge to assure moving the untreated soil, burying the tarp edges into the untreated area for treatment. Injection and tarping are then repeated covering the untreated strips. A third system uses heavier tarps that combine manual, mechanical, and stripping methods of injecting, tarping and covering, allowing multiple spaces between strips. After 1 - 2 days' exposure, the buried far side and ends of the tarp are uncovered, the next strip is injected, the tarp is flipped, and the edges sealed. The process is repeated every 1 - 2 days until each area between the original strips has been treated.

Aerial Application

Agricultural (Plant), Forestry, Ornamental and Turf, (Nurserymen, Turf Managers)

The key to successful aerial application of pesticides is obtaining uniformity of the initial spray deposit over the plant canopy. The chemical will then be redistributed by dew, rain, or overhead irrigation to other parts of the plant including lower leaf surfaces, stems and fruit. The key to uniform aerial application is the design and adjustment of the spray distribution system and the operation of the aircraft.

The advantages of aerial application are summarized below. The most important is the speed of coverage in order to combat widespread and fast developing epidemics when they strike major large acreage crops such as corn, cereal grain, potatoes, and vegetables. One aircraft can do more work in an hour than most ground rigs can do in a day. Aircraft can spray fields that are too wet for ground equipment, which is often the case when fungus pests are most active. Aerial application must be done by a certified aerial applicator.

Advantages of Aerial Application

1. Faster, better timing.
2. Can be used on wet fields following rain or irrigation.
3. Eliminates wheel damage and soil compaction caused by ground equipment.
4. Reduces mechanical spread of virus and bacterial disease.

5. Uses less water.
6. No runoff.
7. Lowers the grower's capital investment.
8. Reduces labor requirements.

Disadvantages of Aerial Application

1. Some fields inaccessible or too uneven or too small for successful flights.
2. Inherent potential for environmental pollution and drift damage.
3. Certain crops and certain pest problems not suited to aerial application.

Calibration

The certified aerial applicator bears the responsibility for correct dispersal of pesticide from an aircraft, however it is good practice for the job supervisor to check performance and require adjustments in a system not delivering the correct amount per unit area. The final calibration should be done with the aircraft in flight; this is the only way it can be done if wind driven pumps are used. In New York State the operator must be certified as an aerial applicator. The following chart and instructions may be used to simplify the calculations:

$$\text{Formula: Acres per minute} = \frac{2 \times \text{swath width} \times \text{miles per hour}}{1{,}000}$$

The chart below shows the rate, in acres per minute, at which spray or dry material can be applied when swath width and speed of aircraft are known. For swath widths or aircraft speeds other than those shown, interpolate or use combinations of the figures shown. To find the rate of flow in gallons per minute or pounds per minute, multiply the acres per minute figure by the number of gallons or pounds per acre to be applied.

Example: A 100 mile per hour aircraft has a 40-foot effective swath. Follow the 40-foot column down until the figure opposite 100 miles per hour is intersected. The aircraft would cover 8.0 acres per minute. If one gallon of spray is to be applied per acre, the aircraft should be calibrated to disperse liquid at the rate of 1 x 8.0 or 8.0 gallons per minute. If 10 pounds of dry material is to be applied per acre, the aircraft should be calibrated to disperse material at the rate of 10 x 8.0 or 80 pounds per minute.

ACRES PER MINUTE CHART

Speed MPH	30' Swath	40' Swath	50' Swath	75' Swath	100' Swath	200' Swath	300' Swath	500' Swath
75	4.5	6.0	7.5	11.2	15.0	30.0	45.0	75.0
80	4.8	6.4	8.0	12.0	16.0	32.0	48.0	80.0
85	5.1	6.8	8.5	12.7	17.0	34.0	51.0	85.0
90	5.4	7.2	9.0	13.5	18.0	36.0	54.0	90.0
95	5.7	7.6	9.5	14.2	19.0	38.0	57.0	95.0
100	6.0	8.0	10.0	15.0	20.0	40.0	60.0	100.0
110	6.6	8.8	11.0	16.5	22.0	44.0	66.0	110.0
120	7.2	9.6	12.0	18.0	24.0	48.0	72.0	120.0
130	7.8	10.4	13.0	19.5	26.0	52.0	78.0	130.0
140	8.4	11.2	14.0	21.0	28.0	56.0	84.0	140.0
150	9.0	12.0	15.0	22.5	30.0	60.0	90.0	150.0

Timing can be done either from the ground or in the aircraft. Radio communication, ground to air, is a help.

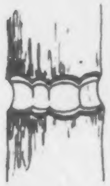
The amount of spray used can be found by measuring the amount required to restore the level in the tank, or if the tank empties completely, a predetermined amount of spray may be added to tank and timed between start of spray and emptying of tank. When calibrating with other than the spray chemical, a material of similar viscosity, or a correction table should be used. Calibration of aircraft should be confirmed in spraying by comparing amounts used with the amounts calculated for an area, as in other kinds of spraying.

Injection and Implantation

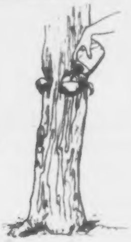
Forestry (Forests - Timber Stand Improvement)

Some herbicides can be applied directly into the trunks of unwanted trees in order to kill them and thus allow desired stems to occupy the growing site. Liquid or dry chemicals can be applied into axe frills (see sketches on following page). Liquid herbicides can also be metered through specialized herbicide injectors (sketches 4, 5). See page 103 for detailed information.

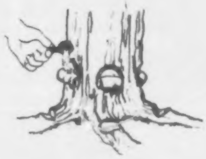
1 GIRDLE



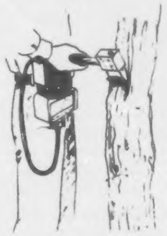
2 FRILL GIRDLE
(spaced cuts)



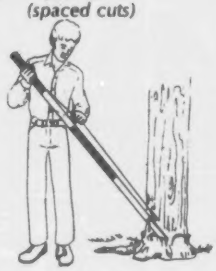
3 FRILL WITH
NOTCHES



4 HYPO-HATCHET
(spaced cuts)



5 INJECTOR
(spaced cuts)



The application of insecticides, fungicides and nutrient elements directly into forest shade and ornamental trees by injection and implantation are relatively new aspects of practical tree care.

Tree Injection

Solutions are fed by gravity or pressure into holes (drilled or punched) in the trunks or root buttresses just above soil line. Ordinarily, injections are made every few inches around the trunk of a tree in order to insure distribution of the chemical into all the major branches. Pressure is usually provided by compressed air, as from the tank of a hand-operated compressed-air sprayer. Pressures of 10 to 40 psi are effective. Best uptake of solutions occurs on warm sunny days when trees are in leaf. Most movement of injected chemicals is upward; injections are not used for pests and diseases of roots. Suspensions containing insoluble particles are not satisfactory for injection because the particles tend to clog the water-conducting vessels of the wood.

Depth of injection is important. Holes that extend deep into the wood are not desirable. The most effective transport of the pesticide occurs in the outermost sapwood. That is where the injector should deliver the chemical. Injection into deeper lying wood results in failure of much of the injected chemical to reach the target -- wood of the current season, bark, or leaves.

Diameter of the injection hole is also important. The smaller the better. Small holes heal quickly.

Because healing processes in trees occur in both the wood and the bark after a tree is wounded for injection, an injection site can be used only once. Within several days after a hole is drilled into healthy sapwood, the tree reacts by isolating the wound from healthy tissues. This occurs before visible evidence of healing. Liquids can neither move into or out of a tree through such a wound.

Advantages of Injection

All or nearly all of the pesticide is placed within the tree where it is more or less rapidly distributed upward to the fine branches and leaves. There is little waste, and hazard of environmental contamination is minimal. Heavy, expensive equipment is not required.

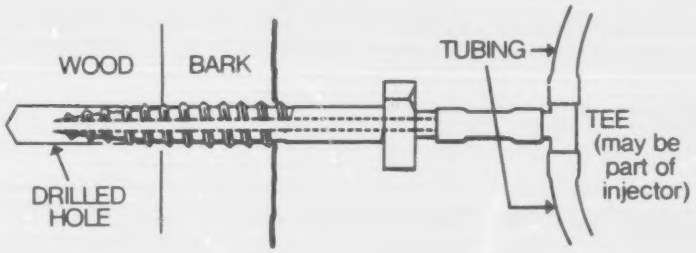
Disadvantages of Injection

Internal distribution of injected chemicals is not uniform. Some branches may receive more chemical than is needed, while others get little or none. For some pesticides applied by injection, the margin between effective dose and phytotoxic dose is small. The proper total dose depends upon tree size and must be determined for each tree to be treated. Bleeding of sap or resin from injection sites sometimes occurs, especially in spring, or if holes have been drilled deep into the wood.

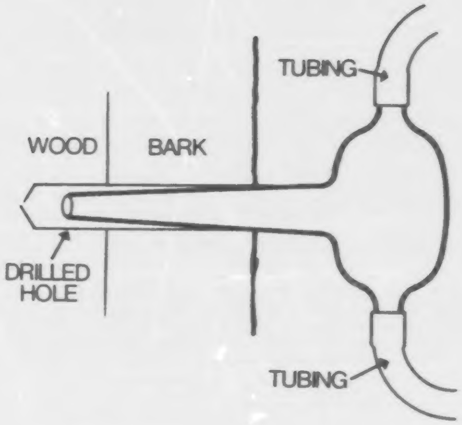
Types of Injectors

There are as many types of injectors as there are innovating people interested in tree injection. Three general types are shown.

1. Threaded pipe tee or lag bolt with drilled center and split tip, turned into drilled hole. A quick-connect or finger-tight fitting

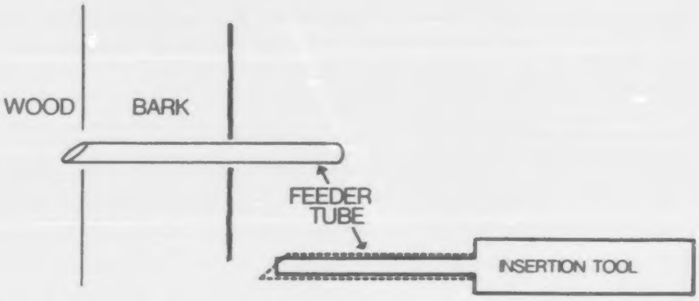


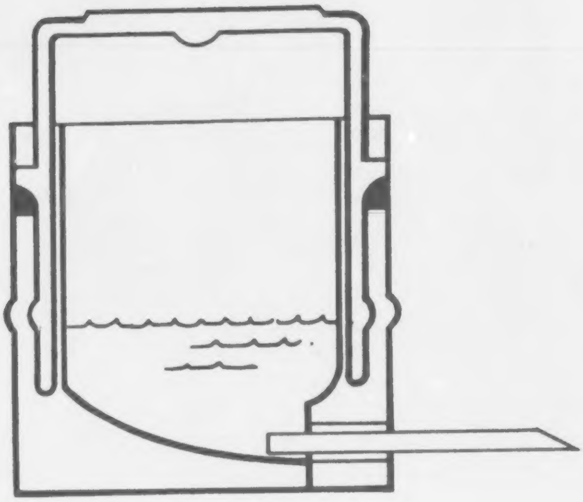
brazed on the bolt head allows connection to feeder line and reservoir.


TUBING
WOOD
BARK
DRILLED HOLE
TUBING

2. Tapered plastic or wood spile, tapped into drilled hole, held in place by friction, connected by finger-tight fittings or plastic connectors to feeder lines.

3. Aluminum feeder tube, driven into trunk using a special insertion tool. Insertion tool has a solid steel shaft on which the feeder tube fits as a sleeve while being driven through the bark. Blunt end of shaft penetrates easily only to the wood, thus positioning the tip of the tube in the outermost sapwood. Feeder tube is then connected to


WOOD
BARK
FEEDER TUBE
INSERTION TOOL

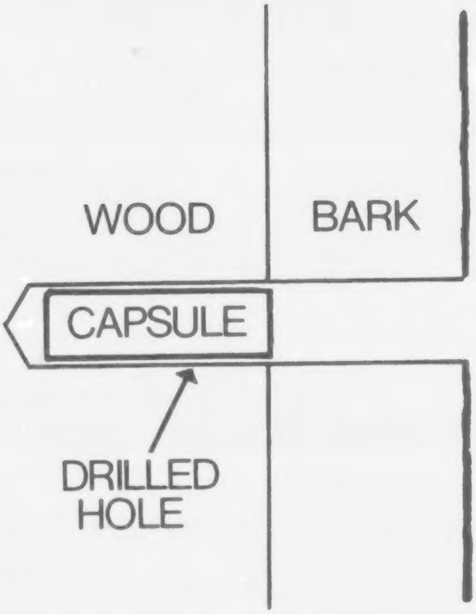


delivery tubing or, usually, to capsules that act as separate reservoirs. Contents may be pressurized slightly, after connection to feeder tube, by squeezing together the two halves of the capsule.

Implantation

Solid chemicals, usually in water-soluble capsules (or plastic capsules with soluble membranes over perforations) are inserted into holes drilled into the outer sapwood. Sap from the living wood dissolves the capsule or membrane and the chemical. This allows the chemical to be carried upward in the sap stream.

Capsules are inserted so that the outer end is flush with the surface of the wood, and are not removed.



In comparison to injection, implantation has the advantage that a tree need be visited only once for application of the pesticide, and no specialized equipment is necessary. The main disadvantage is that the technique can be used only for applying small amounts of chemicals.

OPERATING PRECAUTIONS FOR PESTICIDE EQUIPMENT

1. Never use a pin, knife, or other metal object to unplug a nozzle. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it.
2. Never allow dirty water or debris to enter the tank.
3. Control spray drift by:
    a. Using the largest nozzles and the lowest pressure that will apply the pesticide properly.
    b. Keeping the boom as low as permissible.
    c. Spraying on days without wind or breeze.
4. Do not use corrosive fertilizer solutions in an ordinary weed sprayer. Parts made of brass, copper, steel, aluminum, or even galvanized materials may be severely damaged, unless the sprayer is cleaned carefully.
5. Never operate a sprayer with any of the screens or filters removed. If the screen constantly becomes plugged, replace it with a screen of the proper mesh and capacity.
6. Never fasten a power take-off driven pump solidly to the tractor. The chain provided will keep most sprayer pumps from rotating. Fastening the pump with a bar usually causes rapid bearing wear.
7. Never allow any sprayer pump to run without water, even for a short time; pump seals, bearings, and other working parts may be severely damaged.
8. Always pump a large amount of clean water through the sprayer at the end of the day or when changing from one pesticide to another. Clean all nozzle tips and screens at the same time. This helps reduce the gummy desposits or the accumulations of wettable powders in the sprayer.
9. Airblast sprayers are designed to apply insecticides and/or fungicides. They are used to apply herbicides only in timber production areas -- for control of brush under conifer stands or for selective brush control in regenerating stands. In these cases the standing trees restrict air movement and thus help control drift. When using an airblast sprayer in forests:

- -- Work on a calm day (less than 5 mph wind).
- -- Apply herbicides only in timber production areas.
- -- Follow local regulations regarding distance from crops.
- -- Use operating pressure less than 20 psi.
- -- Use largest practical nozzle openings.
- -- Do not spray under stands of desirable sensitive trees.
- -- Do not spray near recreation areas.

CLEANING THE SPRAYER

There is no satisfactory way to completely remove all traces of any herbicide from a sprayer. Traces of chemicals in solution (2,4-D, for example) cannot be completely removed from porous tanks, or from hoses, pressure regulators, selector valves, or screens. If a herbicide sprayer must be used to apply an insecticide or fungicide, do not apply the insecticide or fungicide to a crop that may be damaged by the herbicide. Chemicals in suspension (such as atrazine) may not be as difficult to remove from the sprayer, but traces may still be present unless all parts are thoroughly cleaned.

END OF THE DAY CLEANING

At the end of the day or whenever wind or weather conditions force you to stop spraying, clean the sprayer to prevent gum or powder deposits in the pressure regulator, selector valve, nozzle tips, and screens.

Follow these steps:

1. Rinse the inside and ouside of the tank three times with clean water.
2. Put in a moderate amount of clean water and spray it out. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system.
3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.

   CAUTION -- Never clean a sprayer near susceptible plants or where the wash water could contaminate farm ponds, streams, or other supplies of water.

STORING THE SPRAYER

When you store your sprayer properly, you add years to its useful life.

1. Clean the sprayer thoroughly.
2. Completely lubricate all moving parts according to the manufacturer's recommendations.
3. Make a list of all faulty parts and order the new ones to be ready for the following spring.
4. Fill the tank with water and add the recommended quantity and type of rust inhibitor or new light oil (see your instruction manual). Drain the tank. Leave all tank openings uncovered for ventilation, but screen them to keep out dust, debris, insects and animals.
5. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of new light oil or kerosene.
6. Take the weight off of any tires.
7. Remove, clean and drain the pump. Fill it with the light oil, anti-freeze or rust inhibitor recommended by the pump manufacturer. Seal all pump openings to keep out dust, dirt, insects and animals.

   NOTE -- Make certain that no water is left in the pressure regulator, selector valve, or the boom. These parts will be severely damaged if water freezes in them.

IV. FORESTS AND FOREST CROPS IN THE NORTHEAST

Forest Regions and Types

Major forest regions and types in the northeastern USA are shown on the map. According to the Forest Survey of the U. S. Forest Service, there are over 75 million acres (117,000 square miles) of commercial forest land in the Northeast, covering 59 percent of the land area.

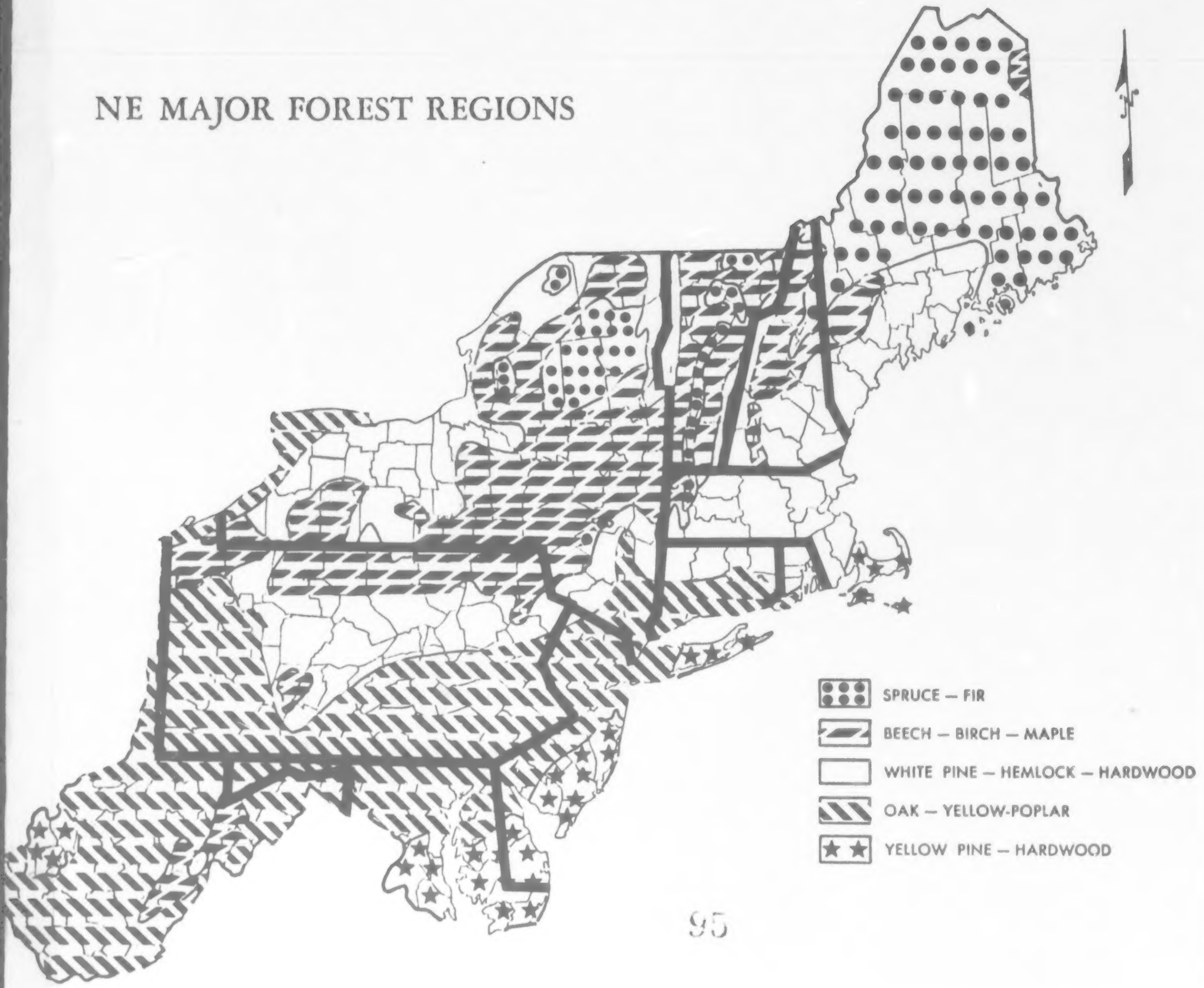
Broadly speaking, there are 5 forest regions: oak-yellow poplar, beech-birch-maple, spruce-fir, white pine-hemlock-hardwood, and yellow pine-hardwood. For example, in the spruce-fir region, red spruce and yellow birch are most abundant. However, individual stands may be composed of a single species (e.g., balsam fir, black spruce, or red spruce) or compatible mixtures (e.g., white spruce-balsam fir-paper birch). Site characteristics may affect stand composition, as is readily seen in swamps where tamarack or white cedar predominate.

Abandoned agricultural land, once reforested, may contain vegetation in various stages of succession. In northern New England, red spruce is frequently found in recently abandoned fields. It gives way to the more tolerant beech-sugar maple-basswood type as time passes. Similarly, white pine in central New England and New York, and red cedar in southern New England, yield to a hemlock-red oak-red maple type. Further south, yellow pines are followed by the oak-hickory type. Over 3/4 of the northeastern forest is now in sawtimber or pole timber.

This forest mixture of types and stand classes is such than an observer driving through the center of any one of the major regions might have difficulty identifying it. Viewed from the air, the separations are more perceptible: the dark spruce-fir streaming southward from Maine along the mountain tops; southward the beech-birch-maple covering the mountain flanks and the plateau of New York and Pennsylvania; to the east and south white pine marking the abandoned fields and otherwise disturbed areas in southern New England and central Pennsylvania; next come the oak and yellow-poplar sites, which include many of the Northeast's farming and industrial sections; and finally the tips of the yellow pine-hardwood types that extend into this region from the south.

As one travels through the region, his impressions of the forest regions would be about as follows:

NE MAJOR FOREST REGIONS


N
SPRUCE – FIR
BEECH – BIRCH – MAPLE
WHITE PINE – HEMLOCK – HARDWOOD
OAK – YELLOW-POPLAR
YELLOW PINE – HARDWOOD

Spruce-Fir

This region characteristically has a predominance of red, white, and black spruces and balsam fir. It occurs in the coolest sections of the Northeast -- in central and northern Maine, the White and Green Mountains, the Adirondacks, and on mountain tops in West Virginia.

Appreciable differences in site or land-use history have modified stand composition. On the best sites, especially after cutting, beech-birch-maple stands prevail. In swamps northern white-cedar may predominate, as white pine does on many sandy sites. After wildfires, aspen and other pioneer hardwoods often temporarily predominate.

Beech-Birch-Maple

The beech-birch-maple region -- often called northern hardwoods -- is composed predominantly of beech, yellow birch, and sugar maple. Common associates include hemlock, sweet birch, red maple, black cherry (in West Virginia and Pennsylvania), basswood, white ash, and northern red oak.

After cutting and fire, the site may be taken over by aspen, pin cherry, or paper birch. Site differences may favor other species; on the poorer and colder sites the spruce-fir intrudes; on sandy sites white pine and oaks may prevail; and in New England and New York swamps, northern white-cedar or black spruce are often dominant.

White Pine-Hemlock-Hardwood

The white pine-hemlock-hardwood region occurs in a zone between the northern hardwoods and the more southerly oak -- yellow-poplar region. Though northern red oak is probably its most widely distributed hardwood associate, other oaks, hickory, and occasionally even yellow-poplar are found in the southern part of this zone. In the northern or higher portions other hardwoods typical of the beech-birch-maple region are common.

Here too stand composition varies greatly with site and land-use history. On old fields or pastures white pine may occur in nearly pure stands, sometimes developing under such earlier invaders as gray birch or aspen. In ravines nearly pure stands of hemlock are common. On sandy plains, pitch pine may form a large proportion of the stand. On cool slopes -- especially after the selective cutting of conifers -- northern hardwoods prevail. Swamps may be covered predominantly by hardwoods such as red maple, black ash, and elm, or in coastal sections by Atlantic white-cedar. In some swamps, particularly in the northern part, spruce may be common. Repeated wildfires tend to favor a composition of pitch pine and bear oak, especially in southern sections.

Oak -- Yellow-Poplar

The oak -- yellow-poplar region might be divided into a white oak-northern red oak-hickory type in the more northerly shallow-soil sections, and a yellow-poplar -- white oak -- northern red oak type at lower elevations or more southerly locations. Because of great differences in elevation, latitude, and soil, characteristic stands within this region vary greatly. In the hills of Pennsylvania or Maryland characteristic species are oaks -- usually black, white, chestnut, scarlet, and northern red. In some sections, as in lower Piedmont of Maryland or near Morristown, N.J., nearly pure stands of yellow-poplar are common. On heavy soils of the upper Coastal Plain more southerly oaks (pin, swamp chestnut, and willow oaks) and sweetgum characterize this region.

There are also intrusions from other regions. Along the northern portion of the zone, hemlock is common in ravines and northern hardwoods may prevail on some northerly slopes. White pine crops out in scattered sections where the sites favor it, as do the yellow pine-hardwood types. Examples of the latter are the Salem Barrens in New Jersey and the Maryland Barrens below Elkton.

Yellow Pine-Hardwood

The yellow pines include chiefly pitch, loblolly, shortleaf, Virginia, and pond pines. On the Delmarva Peninsula, loblolly is the most important species, although pond, Virginia, and shortleaf pines are also common -- especially pond pine and its gradations to loblolly. In southern Maryland the prevailing species is Virginia pine. In New Jersey pitch and shortleaf pines generally predominate, as do Virginia and pitch pines in West Virginia. The yellow pine-hardwood region has the sharpest boundaries of any region in the Northeast because of its close association with Coastal Plain sands.

Associated hardwoods include a wide range of species but are essentially the same as those found in southerly portions of the oak -- yellow-poplar region. On the poorer sites, as where pitch and Virginia pines are usually predominant, hardwoods tend to be mainly dry-site oaks and hickories; although on the pitch pine lowlands of southern New Jersey swamp hardwoods (red maple, blackgum, and sweetbay) and Atlantic white-cedar are common associates. Hardwood associates in the loblolly-pond pine section include a much wider variety: dry-site and bottomland species of oaks, red maple, blackgum, sweetbay, sweetgum, holly, and hickories, to mention a few of the more common ones.

In coastal swamps Atlantic white-cedar and associated hardwoods are common in New Jersey, giving way to cypress and a great variety of hardwoods in lower Delaware and eastern Maryland. On old fields seedling pine stands are common. Protected, formerly cut-over areas usually have predominantly hardwood stands. In New Jersey, poor soils that are burned over frequently by wildfires have only a low growth of pitch pine sprouts and scrub (bear and blackjack) oaks, a marked contrast to old-field stands on 85-foot sites common in some sections of eastern Maryland.

Intrusions from more northern types are usually limited to islands of more fertile soils where yellow-poplar -- white oak -- northern red oak stands predominate.

Seed Production

Forest tree seed has commonly been obtained by harvesting and processing the fruit of forest trees growing in stands managed for the production of other products. More recently, trees of demonstrated worth or improved characteristics have been planted or tended for the primary purpose of producing seed for use in forest nurseries. These forests are given names which designate the intensity of management and genetic characteristics:

Seed Collection Area

This is a forest or group of forests, wild or managed for wood production, designated as a source of seed which produces trees of a genetic quality suitable for reforestation in a particular climatic region. Experience with trees produced from the area, and/or observation of the parent trees is the basis for the designation.

Seed Production Area

This is a forest, often planted, which is managed for seed production. Management may include thinning, cutting of poorly formed trees, topping to keep fruit production within easy reach, pest control, and fertilization.

Seed Orchards

These are orchards planted with trees selected for improved characteristics such as growth rate, form, color, or freedom from pests. The orchards are commonly established with grafted or rooted plants from several sources to reduce the chances of defects arising from the crossing of closely related individuals (inbreeding). These stands are intensively managed to insure maximum production of seed which will produce superior trees.

Seed production areas and seed orchards require intensive pest control to protect the high investment in land and plants, and to assure ample supplies of seed of improved genetic quality. Examples of insect pests that damage forest tree seeds and cones are: pine tip moths, cone worms, seed bugs, midges, seed worms, and pine cone beetles.

Tree Nurseries

The growing of forest trees in a nursery involves an intensive form of management, particularly when the nursery is to be in continuous production for many years. The control of insects, diseases, weeds, and vertebrate pests is a very important part of the nursery management program. Pesticides selected for use in nursery management must not only control the pest, but must be of short residual without any carryover into the following year.

Pest control in nurseries is important to produce good quality disease and insect free planting stock suited to the planting site.

V. MAJOR FOREST WEEDS:
RECOGNITION, BRIEF BIOLOGY, CONTROL STRATEGY

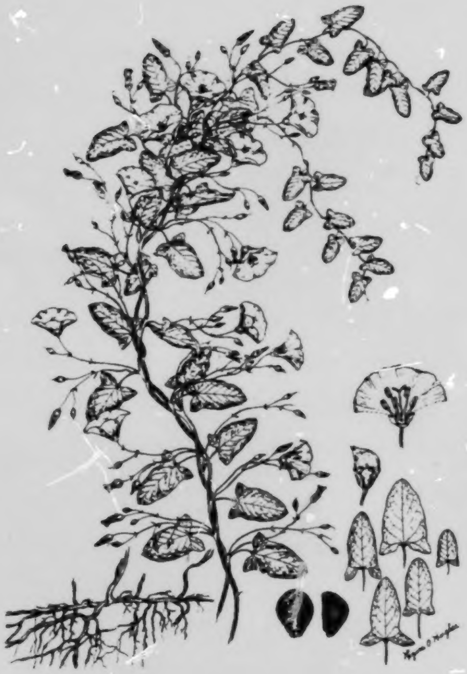
Weeds in Nurseries and Seed Orchards

Why get rid of weeds? Weeds compete with crop plants for water, fertilizer, light, carbon dioxide, and other essentials for growth. The greater the growth of weeds, the less the actual growth of the desirable tree seedlings. The weeds also harbor disease organisms and insects which can build up in and attack desirable plants. Weeds in or near nursery seed beds are a good source for weed seeds or other propagative parts which can infest clean soil.

Modern weed control is an essential part of any effective cultural program. The nurseryman wants to grow seedlings, high-quality plantable stock quickly in a relatively weed-free environment at a minimum cost. The seed orchard manager wants to give the trees a good start in a weed-free environment to reduce maintenance costs. The grower must understand his trees and his weeds to develop an efficient weed control program suitable for his conditions. Removing established weeds costs money.

The complete, well-planned cultural program starts with good soil that is relatively free of noxious weeds. Choose land in the summer when you can determine what weed species are present. If the land is infested with quackgrass, mugwort, Canada thistle, or nutsedge, it may be best to consider another area. If there are no persistent weeds, planting a good cover crop or frequently disking the land for one growing season may reduce the weed population to controllable levels. Other soil treatments may be necessary before planting. Once the soil is relatively weed-free, do not bring in transplants with soil containing troublesome weeds. Place clean plants in clean soil.

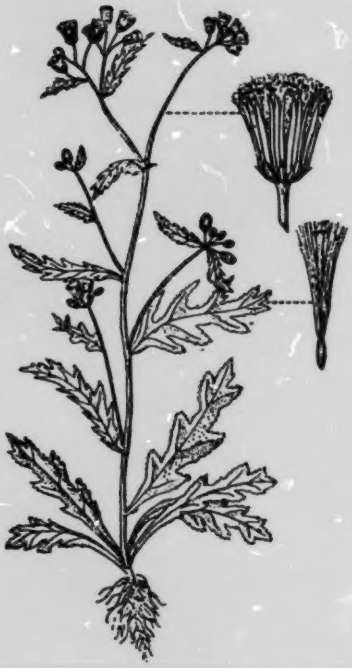
Bindweed



A perennial which propagates by seed and by horizontal roots that bud new plants. The plant grows 2-7 feet long. Stems are smooth, slender, twining, or spreading. Leaf is halberd-shaped (arrow shaped), 3/4 to 2 inches long. Leaf is grooved. The tip of the leaf is round with backward pointing lobes at the base. Flowers are pink, occasionally white, funnel-shaped; about an inch across.

Commonly found in fertile garden and nursery areas. Controlled by frequent cultivation, hand removal of all bits and pieces of root; black plastic and more efficiently by systemic herbicides.

Groundsel

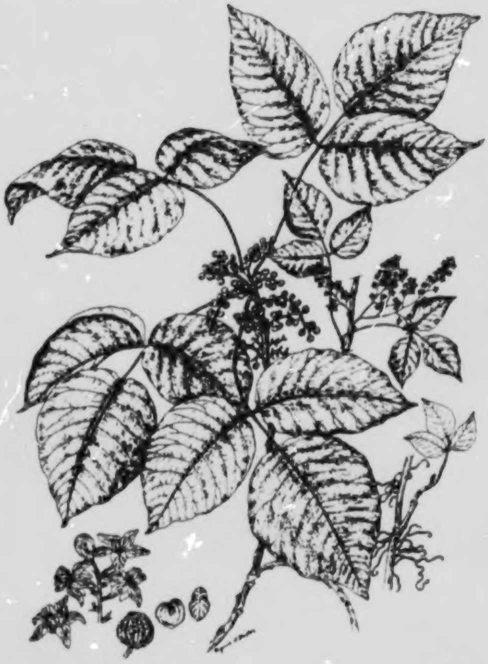


An annual; multiplies by seed. Plants are 4-16 inches tall, simple or strongly branched, with a taproot. Leaves are somewhat hairy, 1-4 inches long, 1/4-2 inches wide, coarsely and irregularly toothed. Flower heads are 1/4 to 1/2 inch wide. This weed, native to the Old World, occurs widely in North America from May into October, surviving mild frosts.

Poison Ivy

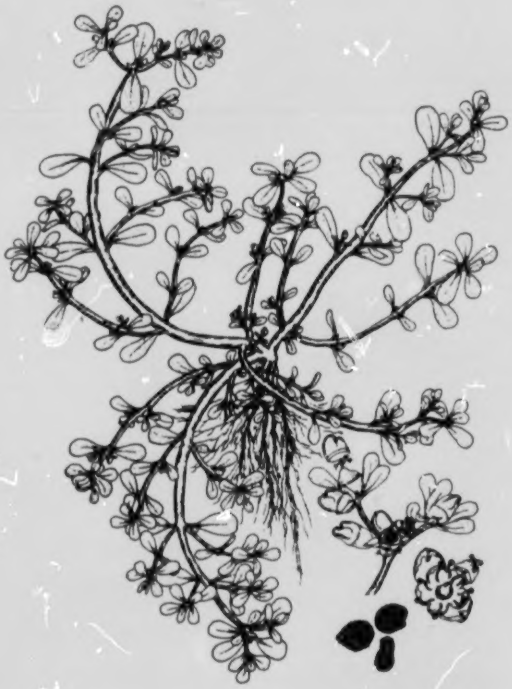
A perennial; multiplies by seeds and creeping rootstocks. Plant upright, trailing, or climbing. Leaves consist of 3 oviate leaflets, 1-1/2 to 4 inches long, smooth hairy underneath. Leaves red or reddish-yellow in the fall. Flowers small, green, in a head 1-3 inches long. Fruit (berries) a cluster of greenish white waxy berries.

Usually found in woods and damp fields. Do not handle. Poison ivy produces a severe rash. Control chemically.



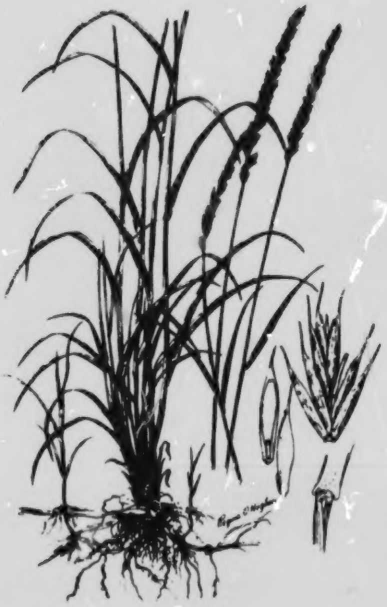
Purslane (Pussley)

An annual; multiples by seed. Few nurseries are without it. Plants are prostrate (lying flat on ground) 4-12 inches or more in length, branching from all sides of the central root. Leaves are small; wedge-shaped to obovate to oblong, 1/2 to 2 inches long, very thick and fleshy. Both stems and leaves have a reddish tinge. Flowers 1/2 inch in diameter, open only in bright sunshine.



Quackgrass (Witchgrass, Couchgrass)

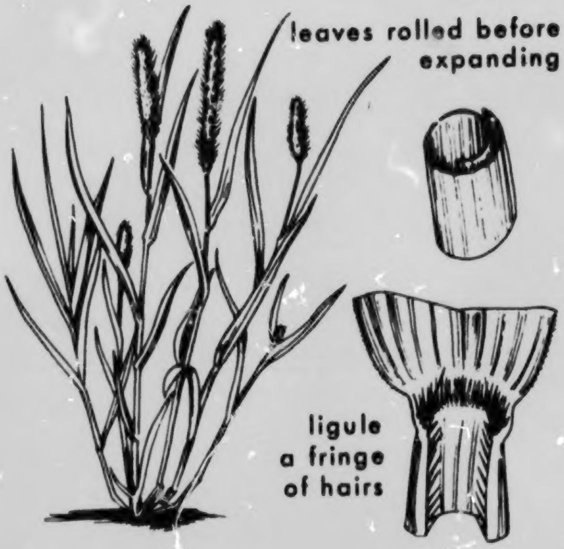
A perennial; multiplies by seeds and yellowish rhizomes (runners, underground stems, rootstocks). Plant 20-40 inches tall. Leaf (blade) 3-12 inches long; 1/8 to 3/4 of an inch wide, sharply pointed, hairy above, smooth below. Flower spikes 4-8 inches long; resembles a slender head of wheat. The most obnoxious weed in cultivated soils. Once it becomes established in the nursery it is very hard to eradicate by cultural means. Frequent cultivations and removal of all rhizomes are necessary since almost any piece of the rhizome is capable of developing into a new plant. Black plastic helps.



Yellow Foxtail

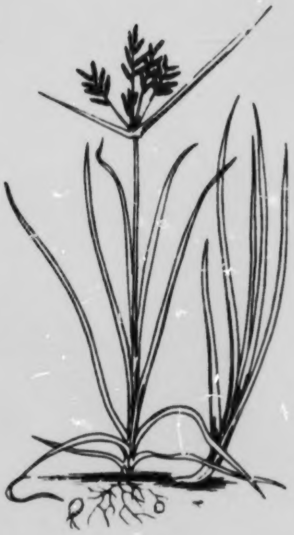
An annual grass; multiplies by seed. Varies from 1-5 feet in height. Leaf blades 3-6 inches long, flat, smooth, seem to have a spiral twist. Large white hairs on the upper side near the base (sheaf) of the leaf. Spikes (seed heads) 2-4 inches long, yellow-barbed bristles give the head a yellow sheen.

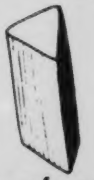
A serious nursery weed; also found in pastures, meadows, and roadsides.



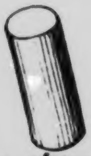
Yellow Nutsedge

A perennial; multiplies by seed and tubers (nuts) on the roots. Plants 4-24 inches high. Grasslike in appearance but not a true grass. Leaves 1/8 to 1/4 inch wide, 3-6 inches long, thick. Flowers dark chestnut-purple; produced on slender stem (spike). A very serious weed in commercial vegetable fields, nurseries, also found in pastures, waste places, and roadsides.





stems of sedges triangular in cross-section



stems of true grasses rounded in cross-section

A very difficult weed to control. The tubers vary in size from a small pea to a very small potato. Tubers are spread on equipment and survive underground many years without growing and then produce a new plant and a new crop of tubers. Black plastic and cultivation aid in control.

Summary - Some Weeds In Nurseries and Seed Orchards

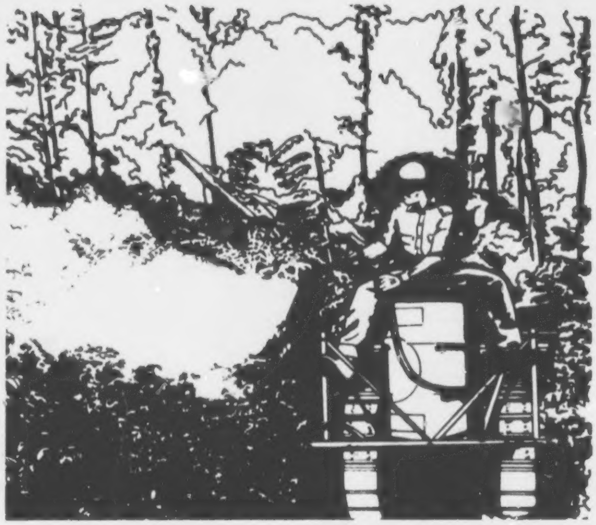
Weed	Classification	Best Timing for Control	Best Stage of Weed for Control	Type of Materials Used for Control	Materials Used
Bindweed (Field)	Broadleaf perennial	Mid-spring or summer	Preemergence for seeding; postemergence for well developed plants	Liquid or granular. Liquid	Selective preemergence Selective postemergence
Groundsel	Annual	Early spring	Preemergence	Granular	Selective preemergence
Poison Ivy	Woody perennial	Mid-spring or fall	Leaves fully expanded	Liquid	Selective-foliar contact or translocated herbicide
Purslane	Annual	Early spring	Preemergence or germinating seedling	Liquid or granular	Selective
Quackgrass	Perennial	Early spring	4-6 inches high	Liquid or granular	Selective
Yellow Foxtail	Annual	Early spring	Preemergence	Liquid or granular	Selective
Yellow Nutsedge	Narrow leaf perennial	Variable	Pre- or postemergence	Liquid or granular	Selective

Weed Control in the Forest

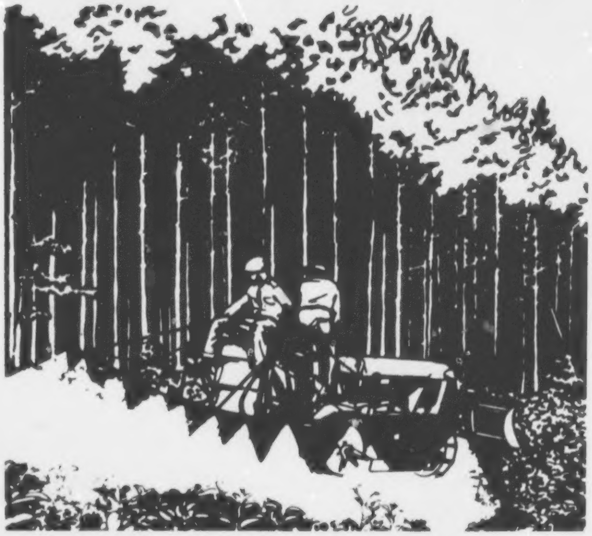
Overstory hardwoods controlled with herbicides to release planted pines

The chemical control of woody plants offers a more economical and effective method of managing undesirable vegetation than hand cutting or other mechanical methods. Herbicides play an important role in planting fields to trees, for conversion of brush to high-yielding plantations, or low-quality cutover forests to vigorous new forests and improved wildlife habitats.

No single chemical or method of application is suitable for all forest or site conditions. Planning your program in advance of application will provide the most adequate control at the least cost per acre. One must assess a given site according to tree or brush size and number of stems to be treated, then choose the proper chemical and carrier, select the right method of application, and later accurately evaluate the results. The use of herbicides is recommended because they are economical, environmentally safe, effective, and versatile in application. These are the basic considerations in a successful program of chemical application in the manipulation of vegetation in forests, pastures, roadsides, and utility rights-of-way. Some chemical control methods applicable to improvement and establishment of of forests are described here.



Tractor mounted gun-type nozzle for high volume spray in hardwood



Tractor mounted boom sprayer for controlling low brush, vines, and weeds

Herbicides

The chemical response, or level of vegetation control obtained after application, will vary according to tree or brush size and density, the kind of herbicide, the volume applied, carrier and active ingredient, season and method of application, species susceptibility, and equipment being used. It is imperative that the forest land managers, herbicide applicators, and particularly the crew foremen familiarize themselves with these factors before application. They can then select the most suitable method or methods for their particular set of stand conditions. Next: READ THE LABEL again before applying the herbicides to be sure the correct formulation has been chosen and applied through proper equipment at the right place, at the right time.

Herbicides most commonly used for establishment and improvement of forest stands are currently available under a variety of trade names. Many of these contain nearly the same chemical and concentration, but with varying amounts of inert ingredients and carriers. Therefore, it is better to become familiar with the common names of the chemicals themselves. Herbicides which have proven most beneficial and effective in northeastern forests are briefly described.

Amitrole - also called Amitrole-T; a white crystalline powder, or water soluble liquid, always mixed with water and applied as a foliage spray; inhibits chlorophyll formation and regrowth from buds; effective in the control of perennial broadleaf weeds and grasses, poison ivy, and Japanese honeysuckle.

Ammate - ammonium sulfamate; a yellow crystalline solid that can be applied as a foliar spray in water solution or as dry crystals or concentrated solution to cut surfaces (frills, notches or cups cut in the bark, or to freshly cut stumps).

Bromacil - a white crystalline solid, formulated as a wettable powder to control a wide range of grasses and broadleaf weeds when sprayed on the soil surface; dry, granular, or pelleted formulations can be used for control of woody plants when applied on soil surfaces; a potent inhibitor of photosynthesis, similar in action to fenuron-TCA.

Cacodylic Acid - also called dimethyl arsinic acid; a systemic herbicide, formulated as a liquid concentrate for tree injection work; will defoliate or desiccate a wide variety of plant species; used primarily for control of undesirable hardwoods and pre-commercial thinning of conifers; applied to trees with a specialized hatchet; rapidly inactivated on contact with soil particles.

Dicamba - also called dichloro-o-anisic acid; the usual carrier is water, applied as a foliar spray or as granules for control of woody plants and brush; when used for the control of individual weed trees, a water solution is applied to spaced cuts at the tree base, using a specially calibrated tree injector.

Fenuron-TCA - a non-selective herbicide used for temporary sterilization in non-crop areas, particularly in brush control; liquid formulations are diluted with water or oil and can be sprayed on foliage, as basal or ground application; granular formulations are applied to the soil as basal, grid or broadcast treatments.

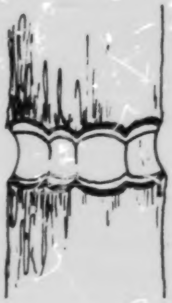
MSMA - also called monosodium methane arsonate; designed for crown kill of undesirable trees through spaced-cut injection methods employing a specialized hatchet; it is useful for the control of jack pine and red pine in the East, and for pre-commercial thinning of conifers in the West; MSMA appears to have a broader utility than cacodylic acid on most hardwood species, because of its greater residual killing action; data on optimum rates for many hardwood species in eastern forests is lacking.

Picloram - for use in controlling thick stands of brush and for certain hard-to-kill hardwood trees or conifers; pellets or beads can be broadcast evenly over an entire area as a non-selective application; for individual tree application, granules or pellets can be applied by hand or with a commercial granular applicator; pellets can be applied in a grid, row, or broadcast manner, similar to fenuron-TCA, and bromacil methods; picloram in liquid water soluble form may be applied as a foliage spray and to individual stems applied with all forms of tree injectors. Active through soil, stem, or foliage. Practical soil persistence is considerably longer than the phenoxy herbicides.

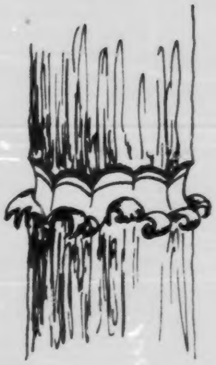
2,4-D; 2,4-DP; 2,4,5-T; 2,4,5-TP - also called the phenoxyacetic acids or phenoxys; this group includes the salts, esters, and amines of the chlorophenoxyacetic acids; the amines and salts are water soluble and applied by diluting with water; the emulsifiable preparation of the esters of 2,4-D or 2,4,5-T may be mixed with water or a petroleum solvent (oil carrier) before application; phenoxyacetic acids are usually applied in liquid form; they are considered truly selective in the control of woody vegetation, specifically when applied as a stump treatment, basal spray or with a tree injector; when applied to large areas of brush for site preparation in advance of planting or seeding, they are generally considered as non-selective herbicides. They may be used for conifer release when correct rate, volume, and timing are used. A mixture of 2,4-D and picloram is commonly used for tree injection into certain hard-to-kill hardwood trees or conifers.

Cut-Surface Treatments: Forest Trees

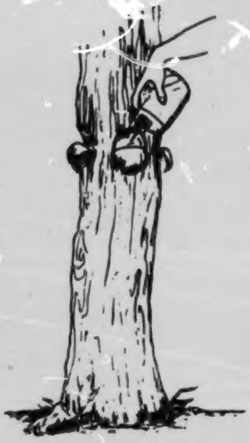
Girdle - used for killing trees, generally 12 inches and above in diameter. No chemical is added. Girdling involves the removal of a 3- to 5-inch-wide band of bark completely around the trunk with single overlapping axe or hatchet cuts. Chain saws are also used to girdle trees. Bark and phloem must be completely severed to disrupt the flow of nutrients to the roots. Sprouting below the girdle may occur; girdling is hard work, time consuming, and costly. Girdling was the first method used for eliminating undesirable trees. This is an acceptable method if sprouting is to be produced for wildlife browse or if sprouts do not interfere with tree seedlings, natural or planted. Girdling is done more easily in spring, when bark separates easily from wood.



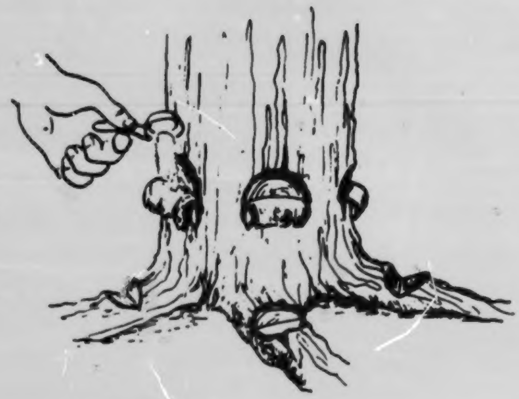
Frill Girdle (continuous cut) - used for killing trees 5 inches in diameter and larger. A single line of overlapping downward axe or hatchet cuts is made completely around the trunk. Do not remove chips. Use an oil can with spout or a squeeze bottle, pouring chemical into "frills" completely around the tree. Frills made 4-1/2 feet above ground are convenient, but on species that are hard to kill, such as hickories, persimmon,



and gums, the cuts should be made around the tree near the ground. Some chemicals, such as picloram, which moves both up and down in the tree, are less sensitive to height of cut, but all are affected to some degree. Trees can be killed in any season with this method, but late spring, summer, and fall are best. This method does not work well on species such as maples during the spring, when heavy sap flow may wash the chemical from the frill.

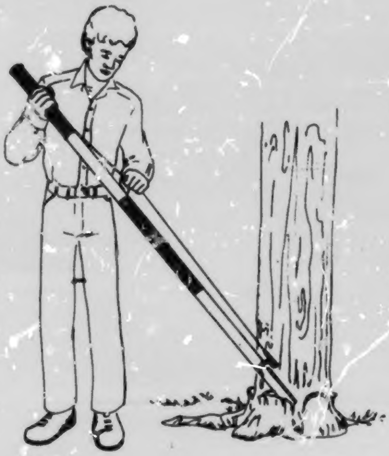


Frill Girdle (spaced cuts) - cuts are made at a convenient height with an axe, spaced 2 inches apart edge-to-edge. The chemical can be applied diluted or undiluted. 1 milliliter (1 cubic centimeter) in each axe cut. If undiluted formulations are used, cuts can be spaced 3 to 4 inches edge-to-edge. Effectiveness will vary with concentration and spacing of cuts. This treatment is effective in any season, but May to August (growing season) is best. On difficult-to-kill species, place cuts closer together and use undiluted formulations.

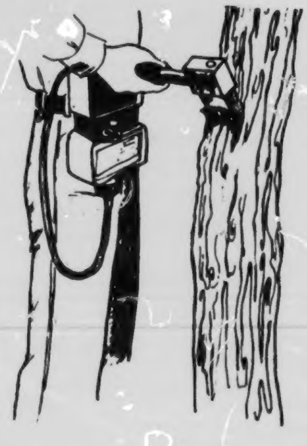


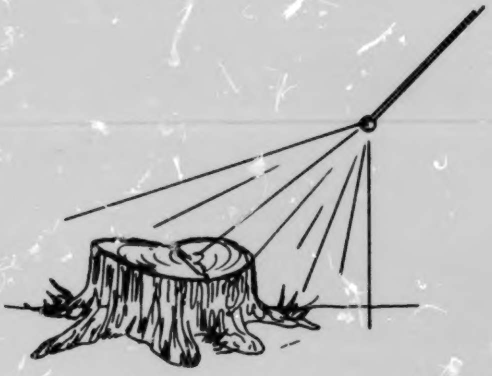
Frill With Notches - notches or "cups" are made with an axe at the base of the tree, spacing 1 cut per each 2 inches of tree diameter, or 4 to 6 inches apart around circumference on larger trees. Two downward axe cuts, one above the other, are made, and the chip is pried out. To each "cup" apply 1 tablesoon of dry, crystalline ammonium sulfamate. This chemical is corrosive to metal and, while of low hazard, may cause skin irritation under prolonged contact. Use plastic spoons and non-metal container when applying. Ammonium sulfamate is a good root translocator and is very effective on hard-to-kill species and prolific sprouters. Generally, treatments can be made at any season, but the growing season is best.

Injector (spaced cuts) - use a special tree injector calibrated to deliver 1/2 to 1 ml of herbicide per cut upon impact, through the bark and into wood at base of the tree. Space the cuts 2 inches apart, or, if a difficult-to-kill species, cuts can be continuous. Undiluted formulations with wider spaced cuts are also effective. Can be used on all species, particularly 2-to 3-inch diameter trees, at any time of year, but May to August treatments are most effective.



Hypo-Hatchet (spaced cuts) - apply incisions waist-high with a specialized hatchet-type tree injector. Apply 1.5 ml per cut depending upon species and season. Most effective on soft-textured conifers, jack, red and white pines of all tree sizes. Useful in pre-commercial thinning of coniferous trees 8 inches in diameter and below. Effective on eastern hardwoods, especially beech, red maple and sugar maple. On hardwoods 8 to 16 inches in diameter, make cuts 3 to 6 inches apart around circumference during any season, but summer and fall are best with spaced incisions. Besides arsenicals, other chemicals such as 2,4-D and picloram can be applied with the Hypo-Hatchet.





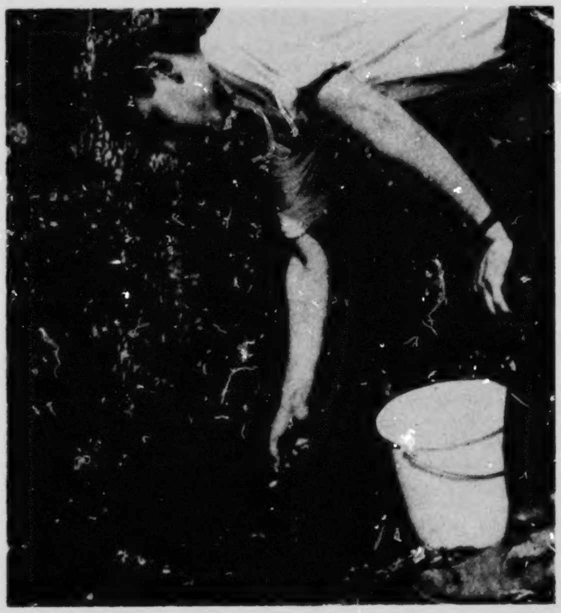
Stump Treatment - as soon as possible after cutting, spray or paint the flat stump surface with herbicide. Make sure that spray reaches the cambium and runs down sides to the root collar. Trees that are smaller than 4 inches in diameter can be "V-notched" with an axe and crystalline ammonium sulfamate placed in the notch with a spoon. This treament is very effective on species such as oaks, maples, beech, and hickories that sprout profusely. However, expect poor root sucker control of black locust, sassafras, and sumac. A spray or dry crystals can be applied at any season, but as soon as possible after cutting.

Bark, Foliage and Soil Treatments: Brush and Forest Trees

Basal Bark - this method is most useful on stems less than 2 inches in diameter, on scattered brush or "clumps" of hardwood brush and small trees. Drench lower 12 to 15 inches of plant stem to the point of runoff, using a solid-cone spray. Often used on species resistant to a foliage spray. Spraying can be done at any season, but dormant season basal stem applications, particularly on utility rights-of-way, are very effective. Expect poor control on root suckering species such as black locust, hickories, and sassafras. Scattered clumps of hardwood brush in pastures and old fields are prime situations for use of basal bark sprays; most effective on thinbarked species. Crankcase oil or diesel oil can be used as a diluent.

Foliage Spray (low volume) - under good growing conditions a water carrier is most often used with this method. Large tracts of mixed brush and hardwoods growing on utility rights-of-ways can be done economically. On areas where low-volume ground sprayers or powered mistblowers cannot be used, small aircraft or helicopters can be employed effectively. Very sparse brush is not ideally suited for this method since the chemical which does not reach the plant is wasted. A drift control agent is often added to the spray mixture. Best results will be obtained from sprays applied during periods of optimum growth after full leaf development. In low-volume ground spraying the objective is to obtain uniform distribution over the brush, rather than drenching of the foliage. Aerial spraying must be done by experienced custom applicators, requiring skilled pilots and highly specialized equipment.

Foliage Spray (high volume) - high-volume foliage applications call for thorough wetting of leaves, stems, and shoots. Size of the brush has a direct relationship to the volume of spray used, since complete wetting of all plant parts is the objective. Water is the preferred carrier with this method; however, under conditions of unfavorable growth, use of oil-water carriers gives a better top kill. For treating brush that is accessible (less dense) to power equipment, this method is most economical. Most high-volume sprays are applied with ground equipment such as truck- or tractor-mounted tank equipment. As with low-volume sprays, late spring and summer, or from time foliage is fully developed, is the optimum time for best results.



Soil Application (dry materials) - dry, non-liquid herbicides are manufactured as pellets, granules, beads, and wettable powders. Applications to the soil surface may be made at any time, but late winter and early spring applications are most effective. They are not recommended for use in marshy areas or standing water. Do not apply to frozen ground. Apply to individual trees or "clumps" of brush on all species and sizes. Depending upon kind of tree or brush, apply as basal (spot), grid, row, or broadcast methods. Effectiveness of control will vary most with soil type and species. Basal or "spot" treatment is recommended for use in pastures and rangelands. Soil applications have been used successfully for release of underplanted seedlings, as a spot following up on utility rights-of-way, in pasture and range development, and for selective control of roadside woody plants. Do not apply within root zone of desirable plants.

Chemical Methods of Forest Weed Control Related to Management Objectives

Silvicultural Objective	Herbicide Objective	Treatment Methods Available
Timber Stand Improvement (TSI)	To improve growth of desirable residual trees and create growing space for tree reproduction.	Girdle, frill girdle, frill with cups, tree injection, hatchet injection, basal bark, and soil application.
Release of Conifers	Low release: from overtopping vegetation (competitors are low shrubs about same height as conifers, or slightly taller).	Foliage spray (low volume) applied with aircraft or powered mistblower, basal bark, and stump treatments.
	High release: from saplings or high understory (competitors are tall brush and low-value hardwoods taller and completely overtopping the conifers).	Foliage spray (low volume) applied with aircraft or powered mistblower, basal bark, frill girdle, frill with cups, stump treatment, tree injection, and soil application.
Planting-site Preparation	To control or set back competing vegetation before planting or seeding; sometimes called pre-planting release.	Foliage spray applied with aircraft, mistblowers, backpack, or ground power pumps.
Pre-commercial Thinning	To control stand density by chemical thinning of dense thickets or coniferous, hardwood or mixed stands that have not reached merchantable size.	Basal bark, tree injection, hatchet injection, and soil application.
Stand Conversion	To remove existing low-value hardwoods to favor desirable timber species; to increase browse value and create openings for wildlife.	Girdle, tree injection, soil application, and aerial application.

VI. MAJOR FOREST INSECTS:
RECOGNITION, BRIEF BIOLOGY, CONTROL STRATEGY

Of the very large number of insects feeding on trees, only a few are serious pests. Insects may kill trees outright, reduce growth, cause deformities, weaken them so that other agents get established, or serve as carriers of agents that cause diseases. In turn, insect populations may be affected by their natural enemies, weather, soil conditions, and general tree vigor.

Effects of insects on the forest may vary. Most deciduous trees can withstand defoliation or moderate borer damage. Disfigured leaves or branches usually pose no great threat of economic loss. In short, many of even the most potentially dangerous insect species may be tolerated, if populations are low. There are notable exceptions; the white pine weevil is a prime example. A few larvae destroying the apical leader may seriously degrade lumber quality in white pine or spruce. Stem-boring insects which are capable of girdling trees may require some management program when their populations are at moderate levels whereas a short-lived epidemic of defoliators may warrant no control action.

The major forest pests may consume needles or leaves (defoliators), infest terminal shoots (shoot borers), tunnel into wood or inner bark (wood borers, bark beetles), or suck plant sap (scales, aphids, leaf hoppers). There are also a number of insects that feed on seeds and cones.

Control strategies for forest insects involve application of knowledge and skills beyond those needed for pesticide application. Outbreaks of forest pests subside naturally; the pest manager must be able to identify outbreaks that will not do so before unacceptable losses occur. These are the outbreaks that may require treatment with pesticides. Assessment of the destructive potential of a pest population requires that the pest manager know how to 1) estimate size of the population and relate this to probable damage levels, 2) estimate the extent of natural predation and parasitism and the incidence of disease in the pest population, and 3) determine prospects for manipulating biological control agents. Control strategies for the forest insects described on the following pages include such considerations in addition to the use of pesticides when needed.

Volatile chemical messenger compounds (pheromones) that influence insect behavior, usually by attraction, are known for several forest pests and may become tools of the pest management specialist in the future. These chemicals can be useful especially for survey and detection work, or perhaps for confusing insect behavior. To date, the exploitation of forest pest pheromones is only experimental.

When the pest management specialist determines that treatment with a pesticide is necessary, timing of the treatment and accuracy of delivery are essential. Multiple passes over or through a given area cannot be tolerated economically. Most approved chemicals have a limited residual effectiveness, mainly for safety reasons, and many of the insect stages are protected at particular times in the life cycle. Therefore timing of the spray with accessible life stages is the goal of the pest management specialist. In addition, timing may be important in order to minimize the impact of a chemical on populations of important natural enemies.

For the Northeast, reference texts valuable to the pest manager include Johnson and Lyon's Insects That Feed on Trees and Shrubs, and Baker's Insect Enemies of Eastern Forests. These should be readily available literature sources.

Beech Scale (See pictures under Beech Bark Disease)

Description

Beech scales are conspicuous on the boles of beech trees due to the white wooly wax they secrete. When infestations are light the wax is evident only as scattered specks at fissures and other roughened places on the bark; heavy infestations may whiten virtually the whole trunk of the tree. A red brown liquid issues from the margins of patches of bark killed by the scale and associated pathogens. The insect beneath the flocculent wax is tiny (1/2 to 1 mm long), yellowish, elliptical, and has rudimentary antennae and legs. The eggs it lays are elliptical and yellow and the crawlers hatching from these are barely visible and appear as yellowish flattened oval specks with well developed antennae.

Life Cycle

The beech scale overwinters as young larvae which complete their development in the spring. As the insects grow they secrete from their abdomens the wax which eventually covers their bodies. The females lay unfertilized (parthenogenic) eggs from late June through July. Eggs hatch beginning in early August and the crawlers move about the bark in search of protected sites to insert their stylets and begin feeding on juices of the inner bark. During the mobile phase the tiny crawlers may be disseminated by wind, and on the bodies of small animals and birds. There is one generation per year.

Damage

Light infestations are not particularly damaging but when the density of scales increases to about 100 per square inch the outer layer of bark is killed and turns brown. The death and shrinkage of groups of cells around the feeding area cause cracks in the bark and thus provides points of entry for pathogenic fungi (beech bark disease) which frequently kill the tree. Enormous numbers of beech trees have been killed in areas invaded by this imported pest and its associated fungi.

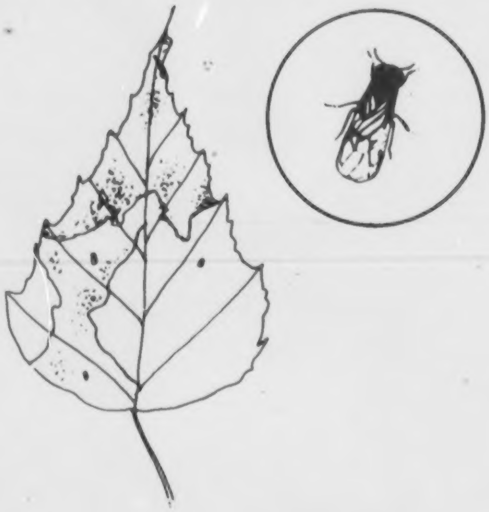
Control Strategy

No proven control strategy is available yet. Commercially valuable beech trees that become heavily infested should be harvested before beech bark disease and the accompanying deterioration of trunks occur.

Birch Leaf Miner

Description

The adult birch leaf miner is a small, black sawfly. It is about 1/8 inch long, with a wingspread of about 1/4 inch. The larvae are small, whitish, and slightly flattened in appearance and when fully grown are nearly 1/4 inch in length.



The larvae and black fecal matter are easily seen in the mines when infested leaves are held up to the light.

Life Cycle

In the spring, during mid-May, the adult sawflies emerge from the soil and fly to white or gray birch trees. Adults are very short lived and are rarely seen except during periods of egg laying. Females crawl over unfolding leaves laying eggs singly inside the soft, newly expanding leaves. The eggs hatch after a week or ten days and the tiny larvae begin to feed on the tissue between the upper and lower leaf surfaces. The mines often unite to form a single large area in which the larvae then live together. After a period of one to two weeks the larvae are mature. They chew through the leaves and drop to the ground where they work their way into the soil, pupate, and later emerge as adult sawflies. A generation is completed in five or six weeks. Since the life cycle from egg to adult is short, there may be two, three, or more generations each year, depending upon location and favorable weather conditions. The second and succeeding generations concentrate on the tops of trees, on terminal or new leaves, and on sprout growth where the leaves are tender. The last generation of larvae at the end of the season remain in hibernation within a cell in the soil until the following spring.

Damage

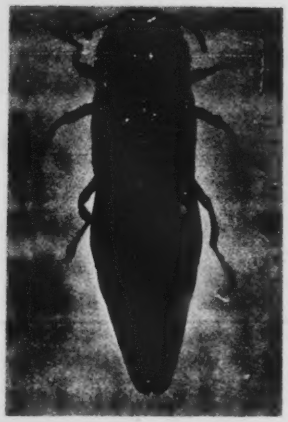
The partially or completely discolored and translucent leaves which later turn brown on birches are signs of damage by the birch leaf miner. Some birches are almost completely browned from top to bottom due to the feeding of the insect. However, the tops of the trees are often the most seriously affected portions.

The first generation of the insect causes the most damage. Adults begin egg laying in the spring at the time the leaves start to unfold. At this time of the year all leaf tissue is soft and favorable for larval development. Old foliage is not attacked by the adult sawflies during their egg laying period.

Normally, a healthy tree can lose part or nearly all of the current crop of leaves without being seriously injured. Repeated leaf losses year after year may kill or seriously weaken the tree, risking attack by serious pests such as the bronze birch borer.

Control Strategy

When necessary for avoidance of stress caused by defoliation, young larvae in leaves can be killed by insecticides before their mining becomes conspicuous. The first generation of miners each year is the most important one.



Adult Bronze Birch Borer

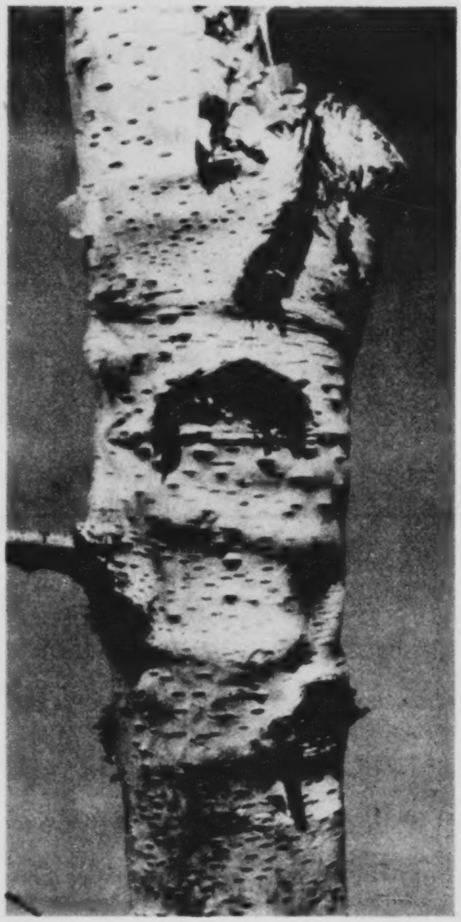
Bronze Birch Borer

Description

The adult bronze birch borer is a slender, olive-bronze beetle with a blunt head. It ranges from 1/4 to 1/2 inch in length. The larva is one of the flat headed borers, pearly white in color and about 3/4 to 1 inch in length.

Life Cycle

Adults emerge in May and early June, depending on seasonal temperatures. The beetles feed for a time on the foliage of birch, aspen, or willow, and eventually the females lay eggs in groups under loose flakes of bark or in cracks and crevices in the bark. The young larvae bore into the cambial layer and begin feeding and constructing galleries beneath the bark. This insect overwinters in the larval stage under the bark and pupates the following spring. Hibernation begins when cool fall weather prevails. The life cycle of this insect is completed in one or two years.



Borer Damage

Damage

The borers attack paper birch, European white birch, gray birch, poplar, cottonwood and willow. The larval stages injure trees by boring beneath the bark on the trunk and larger limbs, sometimes girdling them. Trees of low vigor and those weakened by drought are most suscpetible to attack. The larvae feed in the cambial layer making galleries that wind back and forth usually across the grain of the wood. The tree, or parts of it, are girdled as the larval tunnels interfere with the movement of sap and nutrients in the tree. The tunnels may range up to 5 feet in length. The first sign of damage by the bronze birch borer is the discoloration of foliage and the dying back of branches at the top of the tree.

Successful attack usually begins in the crown in branches about 3/4 inch in diameter. The location of the attack progresses downward year after year. In healthy vigorous trees, the larvae do not complete development and the galleries are healed over causing scar tissue and ridges in the bark.

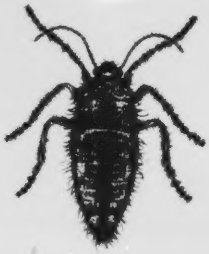
Control Strategy

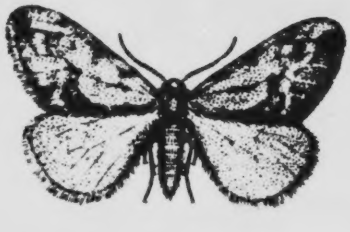
Specific measures for suppression in most forest stands are impractical. Avoidance of damage depends upon avoidance of predisposing factors such as severe defoliation or partial harvest cuts that expose residual stems to microclimatic changes. Individual high-value trees, as around campsites, can be protected by treating trunks and limbs with an insecticide. When properly timed, this will prevent successful egg laying by adult beetles.

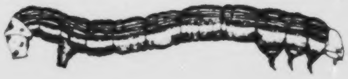
Cankerworms

Description (Spring Cankerworm)

The male moth has a wing expanse of 7/8 to 1-1/4 inches. The forewings are thin and silky with an ash gray color. The hind wings are similar but paler. The wingless female is nearly 1/2 inch long and generally a dark ash gray







with a black dorsal line. Each sex has minute reddish spines in dorsal rows on the abdomen, which give the dorsum a reddish aspect.

The caterpillar has a sooty (grayish-white) white head, mottled with brown, and five pairs of legs. When full-grown, the caterpillars are 3/4 to 1 inch in length, and vary in color from reddish to yellow-brown, green, blue-black or an intermediate color. The broadly oval eggs are a shiny white when first laid, but change to light yellow-brown with age.

Life Cycle

The moths appear in April and May and lay small irregular clusters of fifty or more eggs in bark crevices on the host tree. Hatching and larval feeding occur in early May, about the same time as with the fall cankerworm. When full-grown, the larvae enter the soil. The larvae overwinter in a bare earthen cell where pupation occurs in late winter.

Description (Fall Cankerworm)

The adult male of this species has a wing expanse of about 1 inch. The forewings are a mottled, brownish-gray with hind wings lighter in color.

The wingless female is about 1/2 inch long and an ash-gray color. There are no red spines on the abdomen of either sex as in the spring cankerworm. The full-grown caterpillar has a pale to dark green head capsule which is frequently mottled with black. Its body is about an inch long and varies in color from pale green to brown, black, or reddish-green. Usually there are pale lines running the length of the body and a dark stripe on the back. Six pairs of legs are present, though one pair is quite small and inconspicuous. The cylindrical eggs are gray with brown cap-like tops.

Life Cycle

The moths emerge from the soil in November and December. The eggs are laid in close-ranked, flat masses of one hundred or more on the bark of twigs and limbs. The overwintering eggs hatch in April and early May as the buds open. The caterpillars feed for 4 or 5 weeks. When full-grown they enter the soil and make tough cocoons of silk and dirt particles near the surface. They pupate in early June, but moths do not emerge to lay eggs until November.

Damage

The caterpillars of both species appear on trees in early spring. They destroy the young leaves and buds of a wide range of common deciduous trees, but prefer elm and apple. By the time the larvae finish feeding, only the major veins and midribs of the older leaves remain. Trees may be completely defoliated. If this happens 2 or 3 years in succession, trees may die or be seriously weakened. This is an important leaf-feeding pest in areas where Dutch elm disease is present, because defoliation renders an elm very susceptible to attack by the bark beetles that spread the fungus that causes the disease.

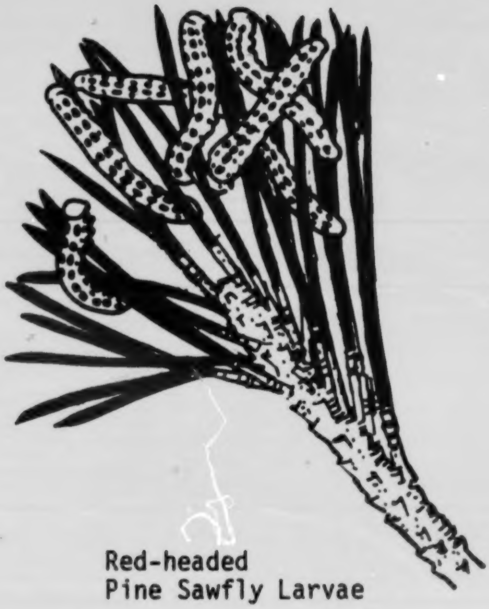
Control Strategy

When necessary, larvae can be killed by insecticidal sprays. Where individual trees have high value, and spraying is unacceptable, the wingless females can be trapped in a band of sticky substance as they ascend the trunk from the soil.

Conifer Sawflies

Sawflies are actually not flies but relatives of bees and wasps that use their saw-like ovipositors to place eggs in the leaves and stems of host plants. Adults of most species described below are robust, about 1/2 inch long and amber or black, except for the larch sawfly which has the anterior half of its abdomen orange.

Larvae are similar to the hairless caterpillars of some Lepidoptera (butterflies and moths) except that there is only one legless segment between the thorax, which bears true legs, and the abdominal segments which bear false legs called "prolegs". There are always at least



Red-headed
Pine Sawfly Larvae

two legless abdominal segments in larvae of Lepidoptera. Lepidoptera larvae, then, have a total of five to eight pairs of "legs", while sawflies have 10 or 11 pairs of "legs". Sawfly larvae can be identified by the color of the head, the color and markings of the body, hosts and egg laying site.

Species	Color		Markings	Preferred Host	Egg Laying Site
	Head	Body			
European pine sawfly	Black	Dark green	Alternating light and dark lateral lines	2 & 3-needle pines	Needles
White pine sawfly	Black	White to light yellow	4 rows of dark spots	White pine	Needles
Red-headed pine sawfly	Orange-red	Yellowish-white	4 rows of dark spots	2 & 3-needle pines	Needles
European spruce sawfly	Brown to black	Green	5 longitudinal white stripes	White spruce	Needles
Larch sawfly	Black	Pale green	None	Larches	New shoots

The cocoons, which are papery red-brown capsules, may persist for several years in the litter beneath host trees.

Life Cycle

The European pine sawfly overwinters in the egg stage within slits that mark the oviposition sites on current-year needles of the host. Eggs hatch in early spring and larvae begin feeding on the old needles at about the time current-year shoots begin to elongate. At first a narrow strip of each needle is not consumed; later the entire needle is eaten down to its sheath. Larvae mature in June and drop to the litter or find other protected localities in which to spin cocoons from which adults emerge to mate and oviposit in September.

The other species described above overwinter in the litter as larvae (prepupae)in cocoons and emerge to oviposit from May to June. Emergence of larch sawflies may persist until August in cold sites. The European spruce sawfly and the red-headed pine sawfly have 2 or more generations per year; the other species mentioned have but one generation.

Damage

Generally sawflies prefer old foliage. Current year needles are not consumed by the European pine sawfly. The new growth beyond needle sheaths of consumed old needles gives branches damaged by the European pine sawfly a lion's tail appearance. The white pine, red-headed and European spruce sawflies will feed on new foliage after the old foliage is consumed; thus, these species and the larch sawfly (larch has only current-year foliage) may completely defoliate and kill their host. The pine sawflies are most serious in plantations because they prefer open grown saplings. European spruce and larch sawflies attack both large and small host trees.

Control Strategy

On the basis of damage projections, insecticidal sprays can be applied to kill larvae.

Elm Spanworm

Description

The larva is a member of that family called loopers or measuring worms, to which cankerworms also belong. The gait is characteristic. Loopers arch their bodies; then while holding to the twig or leaf by means of the hindmost two pairs of legs, they move the forepart of the body forward and grasp the twig or leaf with the forelegs. The body is then arched again, bringing the hind legs (prolegs) forward to begin another "step". The mature larva is about 1-1/2 inches in length with an amber to bright red head and a gray to dark brown body, which appears to mimic twigs. Pupae are pale yellow to dark brown and heavily speckled with black. The adults are white, very frail, with about a one-inch wing span. The eggs are olive green when first deposited and turn bronze or grayish with age.

Life Cycle

Flying adults are evident in July and eggs are laid in compact masses on branches or on the trunks of trees. The eggs overwinter and larvae emerge with the spring foliage flush. They feed during June and when mature pupate in a case constructed of host leaves and silk which is attached to a branch.

Damage

The insect is a defoliator and can completely defoliate large areas of mixed hardwood forests during outbreaks. Hosts include elm, basswood, red maple, yellow birch, and other lowland hardwoods.

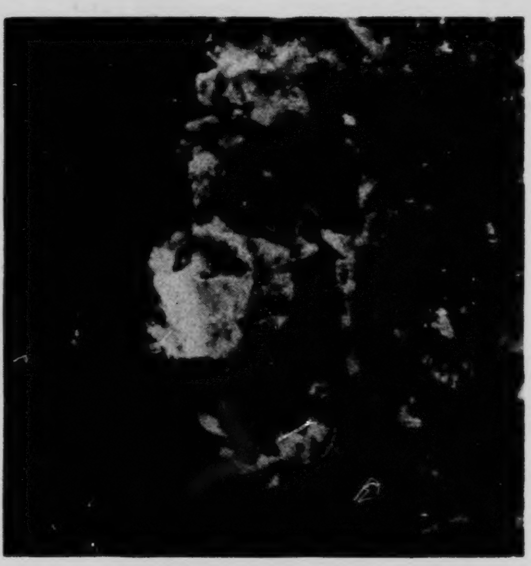
Control Strategy

Larvae can be killed by insecticidal sprays.

European Pine Shoot Moth

Description

This small moth has a wing expanse of less than an inch and is variable in color, although the thorax is usually a rusty orange and the front wings are streaked with irregular silvery lines. The larva is also under an inch in length and dull brown in color, with black accents on the head and the thoracic shield.

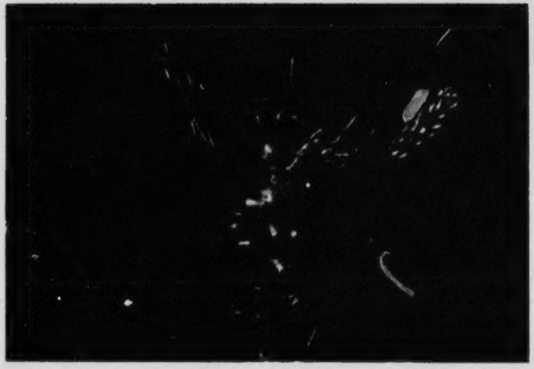


Shoot Moth Larva

Life Cycle

There is one generation per year in the Northeast. Adults are active during June and the first week of July. Eggs are deposited at the base of buds or on needle bases near the tips of host branches. Eggs are yellow and flat when first deposited and turn brown prior to hatch, in about 10 days. The larvae bore into the needle bases, and as the summer progresses, bore into the next year's buds where they construct conspicuous resin-coated webs which appear as yellowish-white masses of pitch. They overwinter as larvae, usually in the mined bud. Pupation commences the following May and lasts for about 2-1/2 weeks.

Damage



Deformed Shoot

The larva is the destructive stage. Evidence of its boring activities is the pitch that is discharged from the infested buds. Although the insect usually does not kill conifers outright, the destruction of terminal and lateral buds will cause distorted growth, severely downgrading the potential timber stock. The larva may also destroy conelets in seed orchards. Damage is most severe in young plantations and seed production areas. As the canopy closes, attack is much less likely.

Control Strategy

Overwintering larvae in and among the buds can be killed by insecticides in early spring.

Gypsy Moth

Description

The female moth is white with yellow to buff hairs on the abdomen. The forewings are marked with irregular blackish bands. There is a line of black dots near the outer edge of each wing. The wingspread is about 2 inches. The female does not fly.

The male moth has a brown body and light to dark brown wings with black markings. Its wings expand to about 1-1/2 inches. It is a strong day flier, and follows a zigzag flight pattern.

The eggs are deposited in masses of 100 to 700 or more and covered with the buff colored hairs from the abdomen of the female. These egg masses are normally about 1-1/2 inches long and about 3/4 of an inch wide. In fresh egg masses, the surface feels like velvet and when the mass is opened the eggs feel like birdshot when they are touched. The fresh masses tend to have a more "lively" color than the older ones, which may present a bleached-out appearance or be otherwise "off color" from weathering.

The hairy caterpillar of the gypsy moth has a dusky to sooty or slate-colored body, and on the back, behind the head, a double row of blue spots (5 pairs) followed by red spots (6 pairs). When mature it is from 1-1/2 to 2-1/2 inches long.

Larval Skins and Pupae

Life Cycle

The female lays eggs during late July or August. The egg masses are deposited on undersides of branches, tree trunks, under loose bark, in stone walls, on fences, or any shady, protected place. The insect overwinters in the egg stage.

The following spring the eggs hatch about the time the trees are coming into leaf in early May, at about the time serviceberry (shadbush) is in bloom. The young caterpillars spin silken threads on which they may be borne long distances by wind. While young they eat "pin holes" in leaves of preferred plants. As they become larger, the larvae devour all green plant material on the host plants. They are fully grown and seek a place to pupate in about seven weeks, or by early July. They spin a few strands of silk, and transform to the pupal or resting stage. The moths emerge in about 7 to 17 days. The males usually appear earlier than the females. There is one generation each year.

Damage

Tree species preferred by the larvae of gypsy moth are oaks, willows, poplars, speckled alder, basswood, apple, gray birch and river birch. Less favored but also eaten by the larvae are the cherries, elm, hickories, chestnut, hornbeam, maples, sweet birch, paper birch, yellow birch, sassafras, black tupelo, and larch. Older larvae will eat native eastern pines and spruces, southern white cedar, hemlock, and beech.

Species disliked by the larvae are black walnut, butternut, ash, catalpa, flowering dogwood, American holly, yellow poplar, locusts, sycamore, red cedar and balsam fir.

One complete defoliation will not usually kill thrifty hardwoods but may be fatal to conifers. However, a single or repeated defoliation of hardwoods may reduce their vigor enough so that other insects and disease-producing organisms are able to attack and kill the tree. Tree losses have been noted after only one or two years of complete defoliation during drought periods on poor sites, and openings in the forest sometimes result.

The aesthetic, recreational, and watershed values of forest, park and ornamental trees can be seriously threatened by this pest. The hoards of caterpillars that occur during outbreaks create a public nuisance.

Control Strategy

Egg mass surveys in outbreak areas are the usual basis for decisions about insecticidal sprays directed at young larvae.

Pine Engraver Beetle

Description

Adults are 1/4 inch long, cylindrical beetles with the posterior 1/3 of the wing covers depressed to form a declivity used to scoop boring dust from the beetles' galleries within the bark. On each side of the declivity there are 4 spines; those of the male are larger than those of the female. Sexually mature adults are dark brown to black while new adults still under the bark of the brood tree may be tawny yellow to chestnut brown. Viewed from above, the head is concealed by the pronotum (part of the thorax). The antennae terminate in a flattened club.

Larvae are legless white grubs with amber head capsules. Pupae are initially white but become yellowish near the time for emergence of the new adult. Eggs are translucent spheres tucked individually into niches cut in the sides of the egg galleries.

Life Cycle

In the late fall adults emerge from brood material to overwinter in the litter near the base of the host tree. When temperatures reach 75°F in May, adults leave the litter to search for host material. A male beetle which locates suitable host material bores into the succulent inner bark to form a nuptial chamber. Brown boring dust (frass) which is pushed out of the entry hole contains volatile chemicals which act as a powerful attractant for both sexes. Newly arriving males promptly bore their own nuptial chambers while females enter the nuptial chambers, mate and proceed to construct egg galleries parallel (or slightly transverse) to the grain of the wood. One to 5 egg galleries radiate from each nuptial chamber; usually 3 females per nuptial chamber produce a completed gallery system with a "Y" configuration. Eggs are deposited in individual niches excavated from the sides of the egg gallery as it is extended. In about 6 days larvae hatch from the eggs and begin feeding by chewing their own tunnels perpendicular to the egg gallery. After 10 to 30 days of feeding a pupal period of 6 - 10 days takes place in chambers at the ends of larval mines. New adults feed on the phloem until they are ready for dispersal flight. Adults from the spring generation emerge from late June to mid-August, depending upon the weather and the amount of warming of the brood by sunlight. These insects attack winter slash which was previously uninfested, new slash, or trees which are stressed from drought or injury.

The earliest emerging adults of the 2nd generation produce a 3rd generation which matures in September and October. However, after the initial spring mass flight of overwintering adults, the beetle broods are not separate from one another because parent adults often emerge and reattack. During every warm day in the summer and autumn some beetles are in flight and new attacks occur.

Damage

The pine engraver beetle mines and breeds in the living bark of its host. This activity kills the host or at least the part of the host that is infested. In the northeastern states the preferred hosts are red, white and Scots pines, but this insect will breed in any pine or spruce available. The adults flying in the spring usually restrict their attacks to windthrown trees and slash. The summer generations often attack mature and pole-sized pines (standing spruces are rarely attacked); tree mortality may be severe when trees are predisposed to successful colonization by drought, defoliation or injury. Populations building up in slash from logging, road construction, etc. may overwhelm apparently healthy trees nearby. This insect also causes indirect damage by introducing fungi which stain and rot the sapwood of pine and spruce logs that are not utilized promptly after they are harvested.

Galleries

Control Strategy

Attacks by this pest begin on weakened trees or slash, then may extend to healthy trees as new adult beetles are attracted to the attack site. Spot outbreaks in high-value stands (e.g. at campsites) can be halted by cutting and removing all trees under attack. Extensive outbreaks, as following fires or windstorms, can both be suppressed by currently available means.

Seed and Cone Insects

Description

Insects which feed on conifer flowers, conelets, cones and seeds are a major factor limiting the production of both cone crops and viable seeds of important conifer tree species in the Northeastern seed orchards. There are a large number of insects that can cause serious seed and cone losses. The types of insects causing damage are listed by the main categories of seed and cone damage they can cause. An example of each insect type is also included.

Damage

Insect Type	Type Damage	Insect Example
Pine tip moths	Destroy conelets on pines	European pine tip moth
Sawflies	Destroy flower buds	Pine sawflies
Seedbugs	Abort conelets and destroy seeds in cones	Leaf footed pine seedbug
Coneworms	Destroy conelets on pines and destroy parts of cones and whole cones	Pine coneworms
Seedworms	Destroy seed in developing cone	Pine seedworms
Midges	Destroy conelets on pine and destroy parts of cones	Cone feeding midges
Coneborers	Destroy whole cones	White pine cone borer
Cone Beetles	Abort cones on pines	White pine cone beetle
Chalcids	Destroy seeds in cones	Seed chalcid (wasp)

Control Strategy

On the basis of damage projections, insecticides may be applied by foliar sprays, tree injection, or granular application as corrective or preventive treatments against the target insect.

Spruce Budworm

Description

The adult insect is a mottled grey moth with a wingspread of nearly one inch. The pale green eggs are laid shingle-like in elongated masses on host foliage. The mature larva is about an inch long and very active within a small tubular nest constructed from silk and branch tips. Color is variable, but generally it is dark reddish brown with a shiny black head. Light colored body tubercles are also characteristic.

Life Cycle

Flying adults are evident from late June to early August and egg laying usually is accomplished by mid-July. The eggs hatch in about two weeks and the young larvae seek shelter under bark scales, where they overwinter. They become active in spring just before bud flush and complete feeding by late June. Pupation occurs in the silk web produced by the larva.

Damage

This insect will infest a number of important coniferous hosts in the Northeast, including balsam fir and spruce. Since balsam fir pollen represents a preferred larval food, outbreaks usually begin in staminate cone bearing fir forests.

Old needles are mined initially, then the new buds of the host trees are attacked. As new growth continues, the larvae tie several twigs together and feed on the growing needles and occasionally bark. The habit of clipping off needles at their base destroys far more foliage than is actually consumed. Heavy defoliation rarely kills the tree in the first year since feeding is restricted to current growth. Usually three successive years of defoliation are required to kill a tree. At this time the current-year needles are removed by the insect and old needles have matured and are shed by the tree. Lighter defoliation may make the tree more susceptible to secondary pests.

Control Strategy

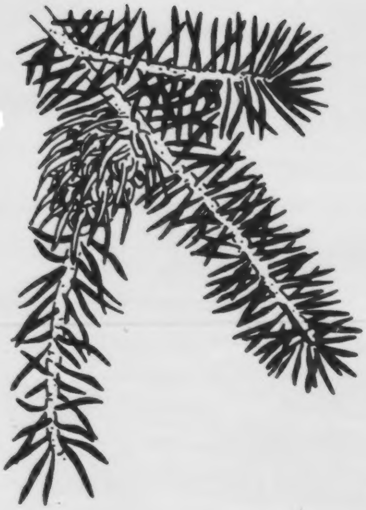
On the basis of population data from observed moth flights and egg mass surveys, insecticidal sprays may be directed at the young larvae when they emerge from the buds and move into the new needles.

Spruce Gall Aphids

Description

Eastern spruce gall aphids produce pineapple-shaped growths 1/2 to 1 inch long, which are usually found near the base of the twig. In early summer, new galls are green with purple or reddish curved markings. Old galls are reddish-brown and have open cavities. Terminal buds are not destroyed until the entire twig dies.

Cooley spruce gall aphids form a larger gall, 1 to 3 inches long, usually infesting the entire tip of the new growth. Terminal buds are injured quickly. These aphids frequently migrate to Douglas-fir as an alternate host, but do not produce galls on this tree. Severe aphid feeding on Douglas-fir may cause yellowing and crooking of needles and partial needle fall, but normally, little disfiguration (real damage) to the tree results.



Eastern Spruce Gall Aphid

Life Cycle

Only females of the eastern spruce gall aphid are known to occur. Immature females winter on twigs, usually near the terminal buds. The insects begin feeding in early spring. When mature, they produce a conspicuous waxy cover under which they lay a mass of eggs. The eggs hatch in a week and the young insects start feeding at the base of the developing needles. Continued feeding induces abnormal growth at the bases of the needles until the aphids are entirely enclosed in a gall of plant tissue where they complete their development.

Cooley Spruce Gall Aphid

Galls and aphids mature in midsummer. The gall dries and splits around the deformed needle bases and the aphids emerge. These young females shed their skins, develop wings and fly to another location on the same or another spruce tree and lay eggs at the base of the new buds.

Immature females of the Cooley spruce gall aphid winter on twigs of spruce or Douglas-fir and produce a waxy covering in the spring. The egg masses are laid on twigs under this conspicuous covering which resembles a small cottony mass. The eggs hatch and the young insects crawl to the developing buds and begin to feed at the base of the new needles, eventually forming a gall. During middle to late summer, the gall opens and the mature aphids emerge. Some females may migrate to Douglas-fir to lay their eggs. The eggs hatch and the young insects winter there. In the spring, they feed on the needles, mature and lay eggs. These hatch and develop into adults that remain on the fir or fly back to spruce to lay eggs for a new generation. The presence of Douglas-fir is not necessary, however, as the aphids can maintain themselves on spruce alone.

Damage

Galls interfere with the natural formation of twigs, causing curling, stunting, and the eventual death of new growth. Heavy infestations give the trees a ragged appearance, destroying their beauty. The insects are a major problem in some Christmas tree plantations. Some trees have a natural resistance or immunity to these aphids, and in spite of the presence of the insects, the galls never completely develop or may not form at all.

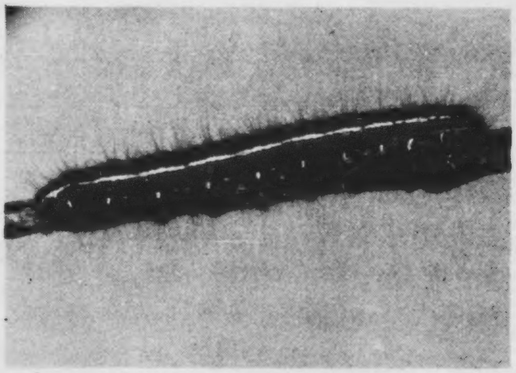
Control Strategy

Insecticidal sprays, early in the growing season, are effective against both nymphs and adults. Maintain separation between Douglas-fir and spruces. Resistant strains of spruces and Douglas-fir are under development.

Tent Caterpillars

Description

Adults of the eastern tent caterpillar (ETC) and the forest tent caterpillar (FTC) are wooly-appearing tan moths with a wing span of 2 inches (female) to 1-1/2 inches (male). Adults of each species can be identified by a pair of diagonal markings on their forewings; those



Eastern Tent Caterpillar

of the ETC are white while those on the FTC are brown.

Eggs occur in cohesive dark colored masses around the twigs of host trees. Egg masses of the ETC are 1/2 - 3/4" long and taper at the ends while those of the FTC are usually shorter and have abrupt margins.

Larvae are sparsely clothed with light colored hairs and have longitudinal markings on a dark background. A conspicuous unbroken white line on its back differentiates the ETC from the FTC which instead has a series of buff-colored key hole-shaped markings. The head capsule of the ETC is black while that of the FTC is light blue mottled with black.

Forest Tent Caterpillar

Cocoons of both species are fuzzy, white and tinted by yellowish powder.

Life Cycle

Overwintering eggs of tent caterpillars hatch about the time the leaves of their host trees begin to unfold. Young larvae feed first on egg shells, then on buds and new leaves. ETC larvae immediately begin to construct a tent at a branch crotch near the site of the egg mass. Larvae congregate within the tent during the day and at night they venture out to feed gregariously on foliage of branches near the nest. The FTC does not construct a nest but forms aggregations on the tree bole during the day and feeds gregariously at night. The caterpillars are fully grown and by mid-June

Eastern Tent Caterpillar Tent

to early July leave the host to spin solitary cocoons on the bark of trees, on fence posts or in the litter. Adults emerge in late June to mid-July mate and lay eggs. Defoliation, adult flight and oviposition of the ETC tend to be completed earlier than for the FTC due to the usual occurrence of the former at warmer sites and lower elevations. Both species have one generation per year.

Damage

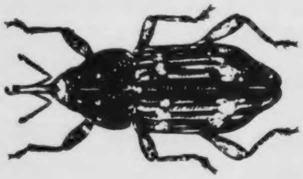
Favored hosts of the ETC are trees and shrubs of the family Rosaceae - especially apple and wild cherries. The most serious economic damage caused by the ETC in the forest is the occasional complete defoliation of valuable black cherry trees. The FTC prefers sugar maple, aspen, poplar, ash, oak, birch, red gum and black gum. Heavy defoliation in consecutive years reduces growth rate and may precipitate the death of many trees. Sap flow in sugar bushes is reduced in quantity and in sugar content following defoliation. Usually natural enemies and diseases interrupt outbreaks of tent caterpillars before widespread tree mortality occurs.

Control Strategy

Outbreaks seldom persist long enough in commercially or aesthetically valuable stands to warrant pesticide application. When necessary, however, the larvae are vulnerable to insecticidal sprays.

White Pine Weevil

Description



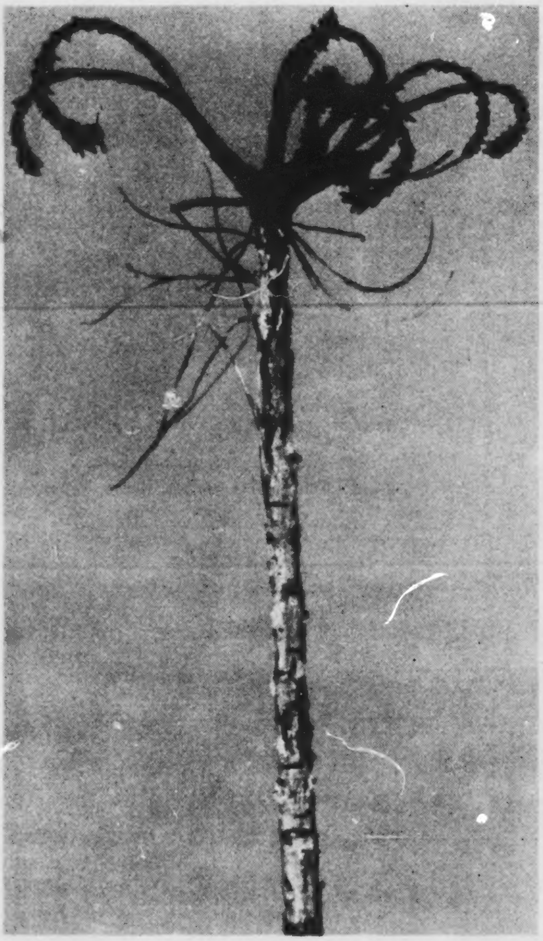
An adult white-pine weevil is about one-fourth inch long and characterized by a distinctly tapered head with a slender protruding beak-like snout. The antennae are located at or just behind the middle of the snout. The eyes are widely separated at its base. The body is covered with tiny reddish-brown and white scales with a distinct irregular patch of grayish-white scales near the rear of each wing cover.

The larva is legless, creamy white in color, and slightly longer than the adult weevil. The head of the larva is small and light brown with distinct eye spots. Larvae are found under the bark or in the wood of an infested shoot.

The pupa is creamy white with brown eye spots and the tip of the abdomen is square. As the pupa approaches maturity the general color the adult is assumed. The pupae are about the same length as the adults.

Life Cycle

The white-pine weevil has one generation a year. Adult weevils hibernate in the litter near the base of host trees. The weevils usually become active during April to early May -- about the time the buds on the white pine begin to swell. On leaving the litter they crawl up or fly to the vertical terminal shoot of the host tree (usually white pine or spruce) and feed on the inner bark tissue. Egg laying may start as early as mid-April in southern localities of the Northeast and extend through June in the more northern areas. A single terminal shoot may contain from 20 to over 350 eggs, depending upon the number of females laying eggs. The female may visit more than one leader to deposit her eggs and any single leader may contain eggs deposited by several female weevils. Resin flows over the bark and eventually fills the chambers con--taining the eggs. Exposure to the air hardens the resin and it acts as a sealing agent. The eggs hatch in five to ten days.



The larvae feed downward beneath the bark, destroying the cambium and inner bark tissue. As they mature they tunnel into the wood and pupate in the pith or in shallow cavities chewed out in the surface of the wood. These cavities are lined with the excelsior-like strips of wood and are called chip cocoons.

Larvae in different stages of development may be found in leaders as egg laying occurs over a month's time. As a result emergence may span from June to September.

Damage

The important external symptoms of attack are confined to the leader and differ depending on the time of year observations are made.

In the spring when adults are feeding, mating, and laying eggs, glistening water-like or dry, white resin droplets may be observed on the leader for a distance of several inches below the terminal buds. The new terminal growth of attacked leaders is darker green than normal. As the season progresses the new growth wilts, turns brown and assumes the form of a shepherd's crook. The bark and needles of the stem below the new growth turns from green to brown as the larvae, feeding under the bark, progress downward. Adult weevils escape to the outside by chewing BB-shot sized holes through the bark. These holes, with chip cocoons under the bark, dried resin, withered stem, and browned foliage identify the injury as that of the white pine weevil although variations of the typical symptoms do occur.

Control Strategy

Adult white pine weevils prefer sunny locations. Young stems in partial shade are less liable to attack than are stems in the open. Thus, uneven aged stand management will result in less weevil damage than will occur in open, even aged young stands. Usually, economic considerations make even aged management and direct protection of susceptible trees necessary. Successful egg laying by adult weevils can be prevented by applying an insecticide directly to the leader.

Weevil-resistant strains of white pine, under development by tree breeders, are not yet available.

Summary - Some Insect Pests of Forest Crops

Name of Pest	Type of Feeding	Plant Type Attacked	Plant Parts Attacked	Life Stage Causing Damage	Life Stage(s) Best Controlled by Insecticide	Injury Diagnosis	Insect Recognition
Beech scale	Sucking	Beech	Bark of the trunk	Adults and nymphs	Nymphs	Decline and death; "beech bark disease"	Fluffy masses of wax filaments on bark of trunk
Birch leaf miner	Chewing	Birches	Foliage	Larvae	Larvae	Mined and browned foliage	Adults are small, black sawflies. Larvae are whitish, found inside foliage.
Bronze birch borer	Chewing	Birch Poplar Cottonwood Willow	Twigs, branches, trunk	Larvae	Adult	Die back of branches at top of tree; brown stain where holes appear on trunk.	Adult is a slender, olive-bronze beetle with blunt head. Larva have flat head, are pearly white in color.
Cankerworms	Chewing	Hardwoods	Foliage	Larvae	Larvae	Defoliation	Larvae colors vary. Size approximately 1" long. "Measuring worm".
Conifer sawflies	Chewing	Pines and other conifers	Foliage (needles)	Larvae	Larvae	Chewed needles, defoliation	Larvae have 3 pairs "true" legs and 8 pairs of "fleshy" legs on the abdomen.
Elm spanworm	Chewing	Hardwoods	Foliage	Larvae	Larvae	Defoliation	"Measuring worm" about 1-1/2 inches long at maturity, with bright red terminal segment and dark brown body.

Summary - Some Insect Pests of Forest Crops (Cont'd.)

Name of Pest	Type of Feeding	Plant Type Attacked	Plant Parts Attacked	Life Stage Causing Damage	Life Stage(s) Best Controlled by Insecticide	Injury Diagnosis	Insect Recognition
European pine shoot moth	Chewing	Pines	Buds, bases of new shoots	Larvae	Larvae	Resin discharge from infested buds; candles don't grow or bend over and become distorted; young candles webbed together.	Brown larvae about 1/2 inch long in tunneled buds or bases of new shoots.
Gypsy moth	Chewing	Hardwoods, sometimes pines, spruces	Foliage	Larvae	Larvae	Defoliation	Larvae hairy and ± 2 inches long when mature. Color is grayish, behind the head is a double row of blue spots (5 pairs) followed by red spots (6 pairs).
Pine engraver beetle	Chewing	Pines	Inner bark	Adults and larvae	None at present	Tree mortality associated with extensive tunneling beneath bark.	Adults brown, 1/4 inch long; larvae tiny legless grubs in tunnels in inner bark.
Seed and cone insects	Chewing Sucking	Conifers	Flowers, conelets, and seeds	All stages	All stages	Aborted conelets destroyed cones, empty seed	Damage on particular tree species differs for each insect type.
Spruce budworm	Chewing	Fir, spruce	Needles, buds	Larvae	Larvae	Defoliation	Adult mottled gray moth with 1-inch wingspan. Black-headed larva with reddish brown body, about 1 inch long when mature.

Summary - Some Insect Pests of Forest Crops (Cont'd.)

Name of Pest	Type of Feeding	Plant Type Attacked	Plant Parts Attacked	Life Stage Causing Damage	Life Stage(s) Best Controlled by Insecticide	Injury Diagnosis	Insect Recognition
Spruce gall aphids	Sucking	Spruces Douglas-fir	New shoots	Nymphs	Nymphs, adults	Galls on twigs	Aphids (adelgids) in cavities within galls; small masses of fluffy wax filaments on twigs.
Tent caterpillars	Chewing	Hardwoods	Foliage	Larvae	Larvae	Defoliation	Larvae make nests, have white line down center of back (eastern tent caterpillar); or dark larvae cluster on trunk, have row of keyhole-shaped marks down middle of back (forest tent caterpillar).
White pine weevil	Chewing	Pines Spruces	Leaders	Larvae, adults	Adults	Browned foliage, dead leaders; and/or resin droplets on leaders. Crook in main stem.	Larvae are small, yellowish, legless; adults are small, brown weevils.

VII. MAJOR FOREST NEMATODES AND DISEASES
RECOGNITION, BRIEF BIOLOGY, CONTROL STRATEGY

Nematodes

Nursery seedlings are vulnerable to damage by nematodes. Continuous cultivation of the same or similar plant species is conducive to the rapid buildup of plant parasitic nematodes. Significant losses can occur where populations are not controlled. Some parasitic nematodes have many host plants including forest tree species. The nematodes most likely to cause damage in forest nurseries of the Northeast are lesion nematodes (genus Pratylenchus), lance nematodes (Hoplolaimus), stunt nematodes (Tylenchorynchus), dagger nematodes (Xiphinema), stubby root nematodes (Trichodorus), and root knot nematodes (Meloidogyne).

Pratylenchus
(Nematodes and eggs in a cherry rootlet, magnified about 50 times.)

Symptoms and Damage

Damage to seedling roots by nematodes can directly or indirectly result in poor growth; nutrient deficiencies evidenced by poor foliar color; increased susceptibility to root rot, water stress, winter injury and frost heaving. The root systems of severely infected plants often appear stunted and, when infected with root knot nematodes, may show numerous tiny swellings. Damage is rarely uniform in the nursery; affected seedlings occur in large patches. Diagnosis of nematode damage depends upon extraction and identification of nematodes from samples of roots and soil. This is a laboratory procedure that requires microscopic examination.

Life Cycle

Nematodes reproduce by laying eggs in soil or infected roots. All of the several growth stages of plant parasitic nematodes feed by piercing the cells of succulent roots with hollow needle-like mouth parts. Some types of parasitic nematodes spend their entire lives in the soil, feeding on the outermost root cells. Other types enter and move within succulent roots. Woody or bark-covered roots are not susceptible. The number of generations per year varies with nematode species and environmental factors, especially soil temperature.

Control Strategy

Keep nematode populations below damaging levels by rotating susceptible with nonsusceptible crops and (or) by treating the soil with a nematicide (usually a soil fumigant).

Annosus Root Rot

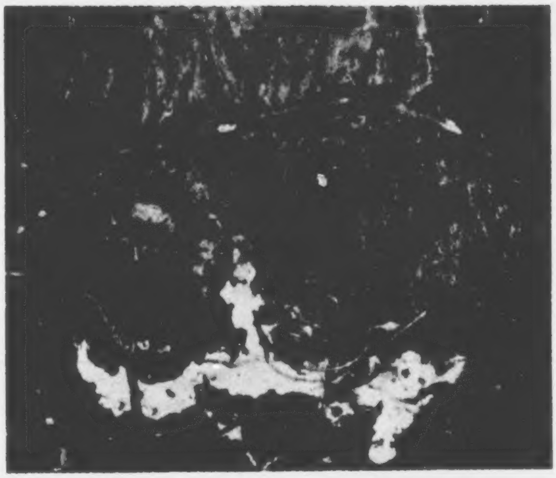
Many kinds of coniferous trees in plantations are subject to root rot caused by the fungus Fomes annosus. In pines the fungus also kills trees. Red pine is most frequently damaged in the Northeastern United States.

Symptoms and Damage

Losses are of three types: outright killing of trees, loss of volume on account of heart rot, and retarded growth.

In pine plantations that have been thinned, look for conks on stumps at the level of the needle litter beginning about 2 years after thinning. Trees adjacent to stumps begin dying 3-5 years after thinning, leaving openings in the plantation. When

Hole in Forest



Conks at Butt

these are numerous and coalesce, the plantation may be destroyed. Infected stands are also abnormally subject to windthrow. Conks form at groundline on killed trees and on roots of windthrown trees. Damage is greatest in valley plantations on sandy soils.

The wood of killed roots shows a stringy white pocket rot. In spruces and other conifers not rapidly killed by *F. annosus*, this rot extends up into the butt log of the trunk.

Root Decay

Disease Cycle

Conks produce spores that are windborne over long distances. The spores germinate on freshly cut or broken sapwood of coniferous trees, such as fresh stumps. When stumps are thus invaded, the fungus grows down into the roots, decaying the wood. Where roots of the stump are in contact with roots of standing trees, the fungus can infect the trees. Root rot thus spreads first from stump to tree and then from tree to tree at a rate of about 2 feet per year in the Northeast. Conks, which serve as local sources of spores, form annually for several years on killed and windthrown trees.

Where an infected plantation is cut and susceptible trees are replanted, mortality, associated with stumps of the first crop, begins after roots of the young trees contact roots of the stumps. *Fomes annosus* cannot grow directly through soil; it spreads underground only by way of roots.

Control Strategy

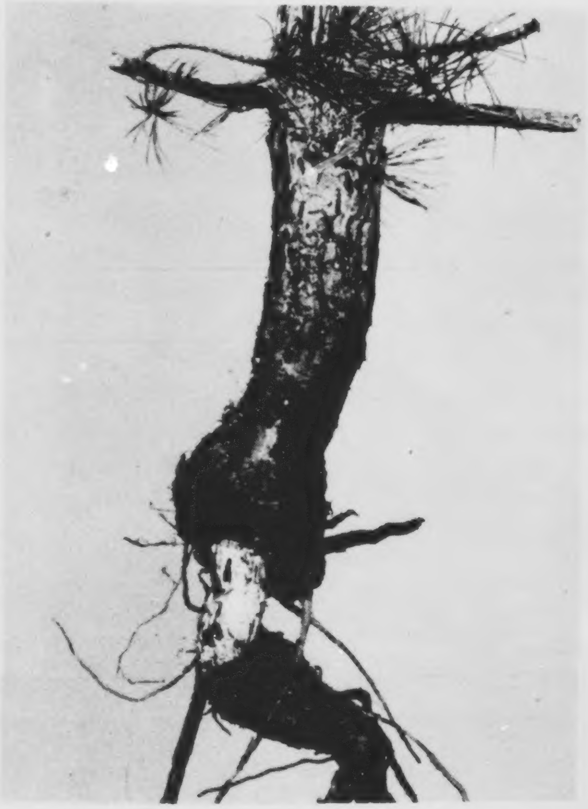
Prevent colonization of stumps by the root rot fungus. This can be done at the time of thinning or harvest by applying chemicals or a biological control agent (a harmless fungus that will compete with the root rot fungus) to freshly cut stumps. Where infection has been severe, convert the stand to resistant species. Most hardwoods are resistant. If high-value trees, as in a seed orchard, are to be protected where the root pathogen already occurs, stump pulling plus soil fumigation can be beneficial.

Armillaria Root Rot

The fungus Armillaria mellea can cause root rot and mortality in hundreds of plant species - both evergreen and deciduous.

Symptoms and Damage

At the base of a dying or recently killed tree, between the bark and wood, look for white fan-like development of the causal fungus. A. mellea kills by girdling trees at the butt or root collar. In conifers, resin may be secreted by infected tissues before death. This will cause soil to adhere to the infected butt or root.



Fans

On root surfaces or extending up from soil between the bark and wood of killed trees, look for dark, shoestring-like strands. These are called rhizomorphs and they are the means by which A. mellea spreads from one place to another in soil.

In autumn, honey colored mushrooms may be produced at the bases of killed trees.

Disease Cycle

Armillaria mellea is already present in most forests of the temperate zones of Earth. From a root or butt of a tree, which serves as a source of food energy, it spreads through soil by means of elongating rhizomorphs. When the tip of a rhizomorph contacts the root or butt of a susceptible tree, a new infection can occur. The likelihood of infection depends upon the size of the food base (source of food energy) from which the fungus is growing, the distance from food base to the susceptible plant, and the vigor of the susceptible plant. A. mellea is widely known for its attacks upon trees that have been weakened by drought, insects, diseases or adverse site conditions. When growing from a large food base, however, it can also kill trees that show no apparent weakness. Healthy trees, especially oaks, often have rhizomorphs of A. mellea growing superficially around their roots; the fungus is present should weakness occur.

Rhizomorphs

Once a root is killed, it becomes a food base from which the fungus can attack the remainder of the root system and from which the fungus can send out new rhizomorphs.

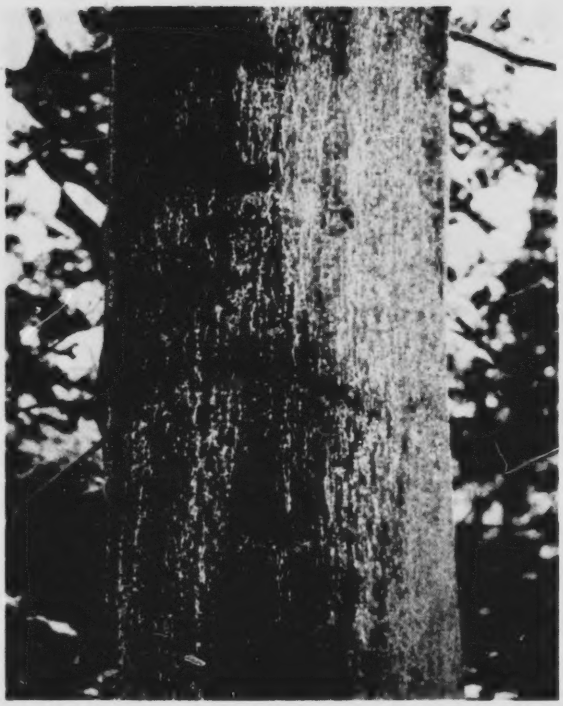
Control Strategy

No practical direct measures exist for control of Armillaris root rot in northeastern forests. The weakening influence of other pests, however, can sometimes be avoided. If trees are protected against defoliation, for example, high susceptibility to Armillaria root rot will be avoided.

In Christmas tree plantations, infection can be prevented or reduced by maintaining separation between the crop trees and nearby hardwood forest. If root rot occurs, reduce the food base by pulling stumps of infected and other nearby trees. If high-value trees, as in a seed orchard, are to be protected, stump pulling plus soil fumigation can be beneficial.

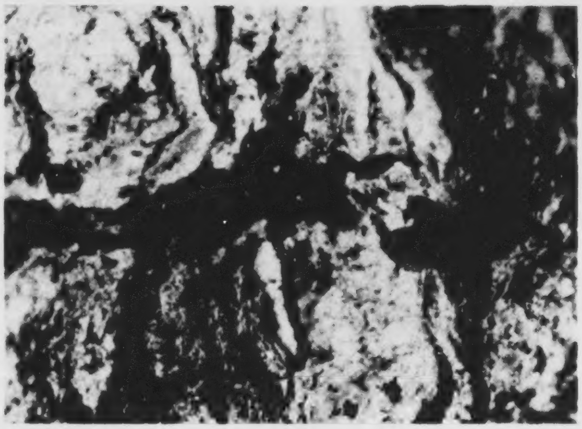
Beech Bark Disease

Beech trees in forest stands are subject to killing or disfigurement by the fungus Nectria coccinea var. faginata, which invades bark previously infested by the beech scale. Having spread south and west from Nova Scotia, beech bark disease occurs throughout northern New England, eastern New York and northeastern Pennsylvania. The beech scale has spread as far as western New York. Trees not killed are usually so disfigured by cankers that they are useless.



Scale-infested Beech Trunk

Symptoms and Disease Sequence



Nectria Perithecia (10X)

The beech scale is described on page 109. Bark weakened by feeding activities of the scale insect is invaded and killed by the fungus, which causes cankers. Bleeding spots on bark often show locations of cankers. As these coalesce, the tree is girdled and killed. On killed bark the fungus produces two kinds of spores that can cause new infections. These spores can be dispersed by splashing water, air currents, or possibly insects. Only one of the spore-producing stages is conspicuous, consisting of masses of tiny (less than one millimeter across) red pimple-like structures called perithecia. Since the beech scale cannot live on dead bark, it disappears before the Nectria fungus produces fruit bodies. Typically, beech scale infestation precedes canker development and tree killing by several years.

Control Strategy

No practical controls have been devised. Commercially valuable beech in the immediate path of the disease should be harvested before its value is destroyed.

Damping Off

Very young seedlings in the nursery may be killed by fungi before or shortly after the shoots emerge from the soil. The fungi most commonly responsible for this damping-off belong to the genera Fusarium, Phytophthora, Pythium, and Rhizoctonia.

Symptoms and Damage

When the germinated seed is killed before its shoot emerges from the soil, this is termed preemergence damping-off. Postemergence infection usually occurs at or just below the soil line, causing the seedling to flop over or wither in the upright position. As seedlings develop woody stems and roots, susceptibility diminishes.

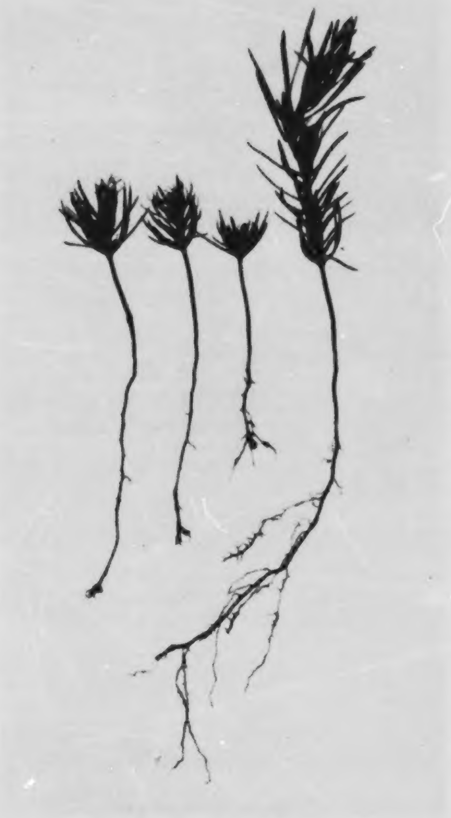
Disease Cycle

The causal fungi are soil inhabitants that build up when soils are repeatedly used for the same crops. Between crops these fungi live on decaying organic matter or survive as resting spores. Damping-off is aggravated by conditions that retard seedling growth. Cool wet weather, a poorly drained seedbed, or high soil pH (e.g. pH 6 to 8) are some of the conditions that can favor damping-off. Also, excess nitrogen will increase seedling susceptibility to damping-off fungi.

Control Strategy

Seed treatments (e.g. stratification), sowing time and seedbed conditions that favor rapid, uniform germination and early growth will minimize losses. In addition, adjustment of soil pH to about 5.5, seed treatment with fungicides, fungicidal drenches for seedbeds, or general purpose soil fumigation will prevent significant losses.

Fusarium Root Rot of Coniferous Seedlings



Douglas-fir Seedlings
(3 affected by Fusarium root rot)

The roots of coniferous seedlings in forest nurseries are often attacked by the fungus *Fusarium oxysporum*.

Symptoms and Damage

In seedlings beyond the stage of susceptibility to damping-off, look for stunting, yellowing, withering of the top, and death. Seedlings with damaged root systems are abnormally susceptible to frost heaving and winter killing. Stunting and mortality develop beginning in mid-summer of the first growing season. Symptoms may continue into the second season. Many infected seedlings, although not killed, never grow large enough for sale and outplanting.

Disease Cycle

F. oxysporum is a soil inhabiting fungus that forms resting spores for survival in the absence of host plants. Infection occurs soon after seed of the susceptible crop germinates, and some strains of the fungus cause damping-off. When infected by a root rotting strain of the fungus, a seedling may not show symptoms above ground until several weeks or months after germination. In adddition to the resting spores that can be transmitted with soil (on equipment, by blowing or by water), the fungus produces other spores that can be wind- or water-borne. Thus, it can spread rapidly in a crop, even where soil has been fumigated.

Control Strategy

Soil populations of the causal fungus can be temporarily reduced by general-purpose soil fumigation. Reinfestation of the soil can be retarded by practices that prevent movement of soil particles and water from place to place in the nursery. Fungicidal soil drenches are of some benefit. High-nitrogen fertilization, which favors the disease, is to be avoided.

Heart Rot

Many different fungi can cause decay in the wood of living trees. Most such fungi eventually produce conks (sources of spores) on the surface of the infected stem. In addition to conks, external indicators of decay are old healing wounds, openings into the trunk, old broken branch stubs.

Heart Rot Conks

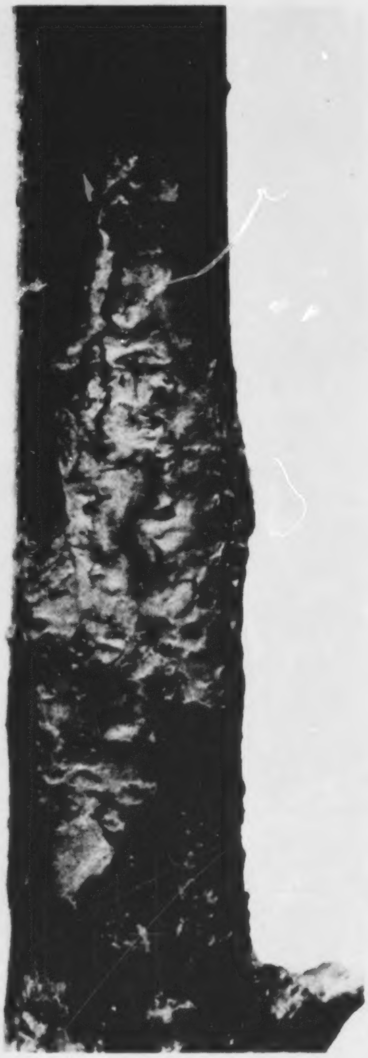
Rot gets started when microorganisms (usually bacteria, then assorted fungi) invade fresh wounds, fire scars or branch stubs. Typically, the decay-causing fungi, which are dispersed as airborne spores from conks, enter wood that has been colonized first by bacteria, then by wood staining fungi. These organisms spread slowly within the tree and usually do not invade wood formed in years following the year of wounding. When a wound, fire scar or branch stub finally heals over, the progression of discoloration and decay from that site is slowed or halted.

A few wood decaying fungi are capable of invading freshly exposed wood not yet colonized by bacteria or staining fungi. The root rotting fungus Fomes annosus is an example.

Control Strategy

Avoid wounding trees. When pruning, do it early in the life of the tree so that the wounds are small and are healed over quickly. In stand improvement work, kill or cut trees that show external indicators of extensive heart rot.

Hypoxylon Canker of Aspen



Hypoxylon mammatum, the fungus that causes Hypoxylon canker, is the most important pathogen of trembling aspen and occurs commonly also on big tooth aspen. The disease is common wherever aspen grows in the Northeast.

Symptoms and Damage

On branches or mainstems the normally greenish to gray bark becomes discolored yellowish-orange in irregular, elongate patches. The interior of this killed bark has a mottled or laminated black and yellowish-white appearance, and the wood beneath the canker is also discolored. As the canker enlarges, the outer bark in the oldest, central portion sloughs off, exposing the blackened, crumbling inner bark. The causal fungus kills trees by girdling and weakening the stem. The wood behind the canker face is decayed and the stem is subject to breakage at this point.

Disease Cycle

In the dead bark of the canker the causal fungus produces two kinds of spores capable of causing new infections. The spores can be carried by air currents or splashed by water. Infection is assumed to begin in tiny wounds. Common sites of infection are branch junctions on 2- and 3-year old stems and wounds made by insects. Spore production begins at least 1 year after infection and continues for several years in a given canker. Stem girdling and death occur 4 or more years after infection starts.

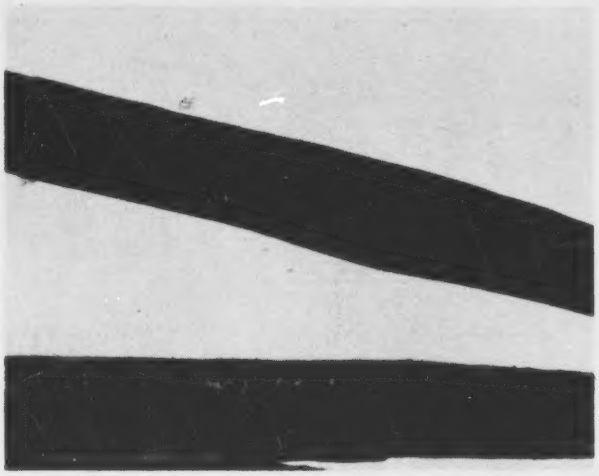
Control Strategy

No control measures are known. There is some evidence of genetic variation in susceptibility, but resistant trees are not yet available to forest managers.

Lophodermium Needlecast of Pines

Several kinds of plant pathogenic fungi cause death and premature casting of pine needles. One of these pathogens, a species of Lophodermium, causes significant damage in Christmas tree plantations. Short-needle varieties of Scots pine, especially the Spanish and French-green types, are the most susceptible.

Dead Needles



Fruit Bodies on Dead Needles

Symptoms and Disease Cycle

Prominent symptoms appear in spring when 1-year-old needles die and turn straw colored. In spring and early summer the dead needles fall from the twigs. If infection is severe, nearly all 1-year-old needles may be cast. With repeated severe infection, trees become stunted. Within only a few years, the fungus can spread from a single infected tree to nearly all trees in a plantation. Many individual trees seem naturally resistant; they remain green while adjacent trees become heavily infected.

Infection occurs once annually in late summer and early autumn. At that time microscopic spores of the fungus are produced in tiny, black, elliptical fruit bodies in dead needles, either lodged among branches of the tree or, usually, lying on the ground. In wet weather the spores are ejected into the air. Those landing on current-season pine needles germinate, and the fungus grows into the needles. The first symptoms are inconspicuous yellow spots. These enlarge and intensify during the autumn and winter, developing brown centers and then coalescing. Infection is usually most severe on the lower branches because they are close to the source of spores, and moist conditions favorable for infection occur more frequently and last longer close to the ground.

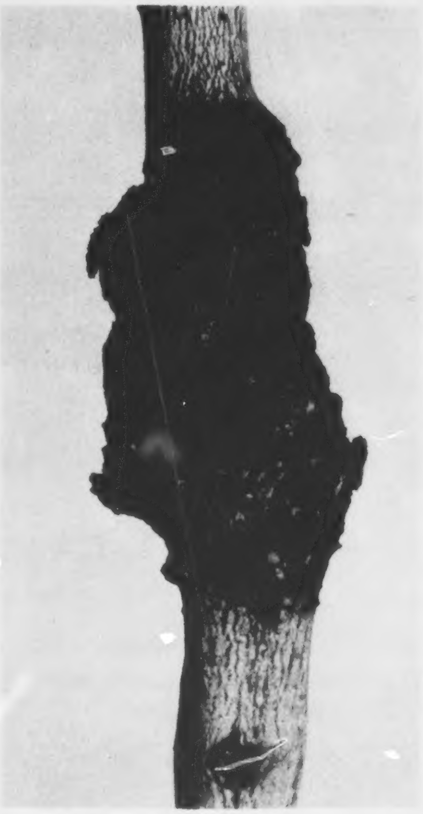
Control Strategy

Plant disease-resistant strains of pine. Plant on slopes and control weeds to encourage air circulation and drying around low branches; this makes the local environment less favorable for disease. Fungicides can be used to prevent disease in the nursery or to reclaim infected plantations. In nurseries, avoid using pine windbreaks; they may harbor the needlecast pathogen.

Nectria Canker of Hardwoods

The fungus *Nectria galligena* causes perennial cankers on many species of deciduous trees in the Northeast.

Symptoms and Damage



Cankers (dead areas in the bark) usually develop at branch junctions on small stems. They enlarge slowly over a period of many years, killing successive callus rolls that the tree produces as a healing response. The result is often a target-like appearance. Occasionally the cankers become elongate, but the distinctive concentric ridges of killed callus are still visible. The bark sloughs off the old parts of the cankers, exposing the wood surface, which weathers to a gray color. Species most frequently infected are maples, birches, basswood, scarlet and black oaks.

Because the cankers enlarge slowly, and decay of wood beneath the canker face is infrequent, infected stems may persist alive for many years. The chief damage is the defect represented by the canker itself, usually in the butt log.

Disease Cycle

The causal fungus fruits inconspicuously on bark dead for 1 year or less, near the edge of the canker. It produces spores that can be carried by air currents or splashed by water. These spores, if introduced into tiny wounds in the bark of young stems, are capable of starting new infections.

Control Strategy

Kill or cut infected stems during stand improvement work.

Oak Wilt

The fungus Ceratocystis fagacearum causes a systemic infection of the sapwood of oaks, resulting in death. Species in the red oak group are highly susceptible; members of the white oak group are somewhat resistant. In the Northeast oak wilt is found only in West Virginia and southwestern Pennsylvania.

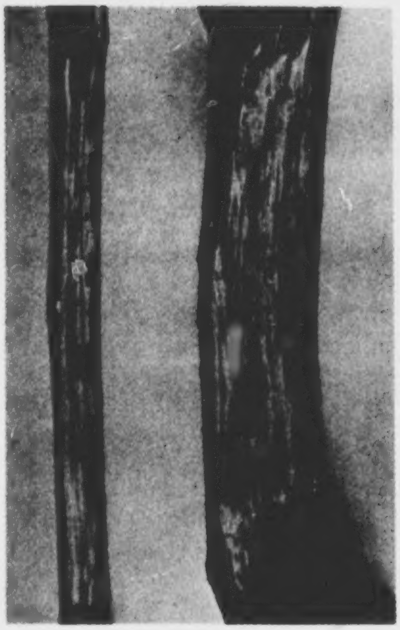
Wilting Tree

Symptoms

In red oaks a wilting and bronzing of the leaves starts in one or more branches near the top of the tree and the leaves fall as symptoms develop. Red oaks usually die during the first year of symptoms. In white oaks the appearance is a branch-by-branch wilting and dieback that may continue several years or even subside. In the outermost sapwood one can observe brown streaks.

Disease Cycle

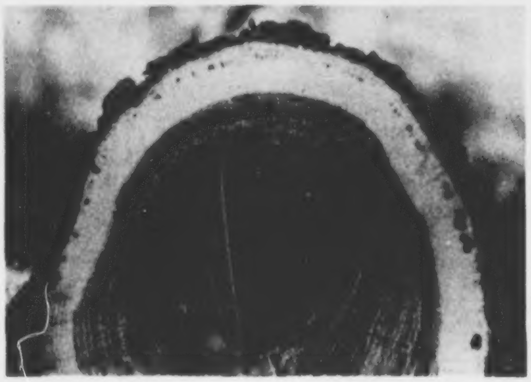
The oak wilt fungus is transmitted from killed to healthy oaks by sap beetles (family Nitidulidae) and by oak bark beetles (Pseudopityophthorus spp.) Sap beetles contaminated with spores of the fungus may inoculate fresh wounds, such as pruning wounds or storm-caused injuries. Oak bark beetles chew into twigs, thus allowing the fungus access to the susceptible wood where it multiplies and spreads. The oak wilt fungus can also spread locally, among oaks of the same species, through naturally intergrafted roots. Thus, when one tree develops symptoms, others around it often follow.



Streaked Wood

Control Strategy

For a time it was feared that oak wilt, being similar to Dutch elm disease, would cause devastating losses in oak forests. The control strategy involved intensive surveys and eradication efforts. In recent years, with the knowledge that oak wilt is neither spreading into new areas nor intensifying rapidly where already present, no control measures are thought to be necessary in Northeastern forests. Note: landscape oaks in oak wilt areas should not be pruned in spring or early summer.



X-section Showing Streaks

Pine-Pine Gall Rust
(Western Gall Rust)

Symptoms

The fungus Endocronartium harknessii causes globose galls on twigs, branches, and mainstems. The disease is known as western gall rust, Woodgate gall rust, and pine-pine gall rust. As the last name indicates, the rust fungus spreads directly from pine to pine. Many species of 2- and 3-needle pines are susceptible. Damage in Scots pine Christmas tree plantations has increased in recent years. Severe infection can result in poor growth, poor foliage color, and death of twigs, branches, or entire trees.

Individual Scots pines vary greatly in susceptibility. Gall-free and heavily galled trees from the same seed source may be seen growing close together.

Disease Cycle

Infection occurs in late May and early June when powdery yellow masses of spores are liberated from blisterlike fungus structures which break through the bark of mature galls and then rupture. The spores are carried by air currents. Spores that lodge on succulent new shoots germinate during wet weather and start new infections. Symptoms can be seen a year later when swellings develop in 1-year-old twigs. When these young galls are numerous, they give a swollen, beaded appearance to infected twigs and usually cause twig death. The rust has a 3-year life cycle: i.e., galls produce spores 3 years after infection starts.

Damage

Galls that do not kill the host branches may enlarge for many years, in extreme cases reaching a diameter of 15 centimeters or more on old trees. Beginning usually 3 years after infection, living galls produce spores that initiate new infections. Most spore-producing galls are between 2 and 6 centimeters in diameter.

Control Strategy

Keep infected plants away from healthy ones. Examples: prevent seedling infection by destroying infected pines growing in or near nurseries. Cull galled seedlings at the nursery or as discovered when planting. Rogue infected trees discovered in young plantations. Fungicidal control of this disease is possible for reclamation of heavily infected Christmas tree plantations.

Rhabdocline Needlecast of Douglas-Fir

Fungi in the genus Rhabdocline cause purple-brown spotting and premature casting of needles of Douglas-fir in Christmas tree plantations and occasionally in nurseries. The disease does not often occur on ornamental Douglas-firs in landscapes.

Symptoms and Disease Cycle

Beginning in autumn and winter, purple-brown spots 1 - 2 mm across develop on green 1-year-old needles. When numerous, the spots coalesce. The base of each infected needle stays green. From late winter into June, infected needles fall. Tiny blisters less than half the width of the needle develop in May on the lower surfaces of brown spots on infected needles still on the tree. The blisters, the same color as the spots, are sources of spores that are carried by air currents to developing foliage. The spores germinate and cause new infections in May, but no new symptoms show until the purple spots begin to develop again in autumn. In summer the only symptom may be absence of needles from 1-year-old twigs. Repeated severe infection will destroy the economic value of a Douglas-fir Christmas tree.

Control Strategy

Rhabdocline needlecast is favored by moist conditions and poor air circulation around low branches. Plantations on slopes and where weeds are controlled are least likely to be seriously damaged. The pathogen can mature and produce spores only in needles still attached to the twigs. Thus, by early detection (in March and early April) followed by roguing severely damaged trees and pruning the low infected branches of other trees, the disease can effectively be suppressed.

Scleroderris Canker

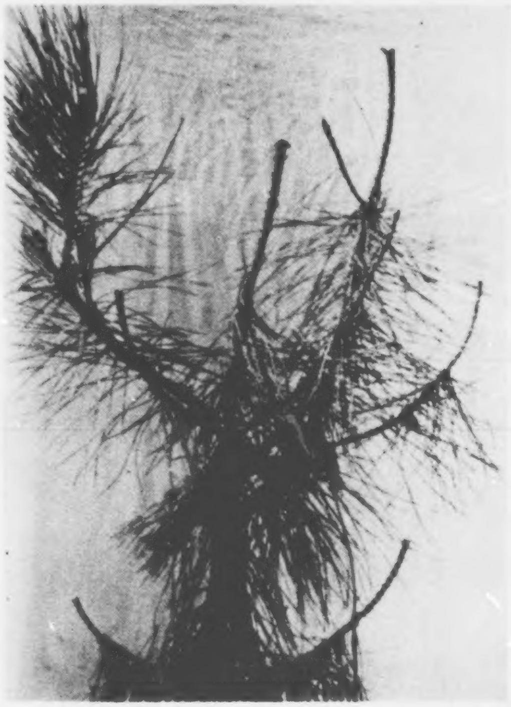
Young, hard pines in nurseries and plantations in the Adirondacks region of New York and in other northeastern areas with comparable climatic conditions are subject to killing by the fungus Scleroderris lagerbergii, also known as Gremmeniella abietina.

Orange-brown Needle Bases

Symptoms and Damage

Small trees and the branches of larger ones are killed by girdling which occurs in cool weather. The first conspicuous symptoms develop at needle bases, where the normally green tissues become orange-brown in early spring. Foliage of the killed twig or branch is uniformly brown. A characteristic yellowish-green color can be seen just beneath newly killed bark in a canker. Once established in a plantation, the disease cannot be controlled.

Red, jack and Scots pines are highly susceptible: many other coniferous species can become infected.



Branch Mortality

Disease Cycle

Infection occurs in late spring or summer. Symptoms may occur during the same year or the next spring. On bark of cankers and newly killed twigs the causal fungus produces spores that can be water-splashed or possibly carried by insects to cause new infections on buds or needles. Air-borne spores are produced one year after death of the bark or twig. Thus, the disease has a one-year multiplication time while the causal fungus requires two years to complete its entire life cycle.

Control Strategy

Avoid infected nursery stock. In regions where the disease occurs in nurseries, it can be prevented by fungicidal sprays, thus insuring "clean" planting stock. Planting stock can also be procured from nurseries outside the cold, snowy regions where Scleroderris canker occurs. New plantings of susceptible species should not be established near trees known to be infected.

White Pine Blister Rust

White pine blister rust, caused by a fungus, Cronartium ribicola, is one of the most important diseases of white pine in the northeastern United States. Susceptible to this disease are white pines, especially young trees, and plants belonging to the genus Ribes (currants and gooseberries). Blister rust is a foliage disease of no direct importance on Ribes plants, but on white pines it is lethal if allowed to spread from an infected branch into the trunk.

Blisters

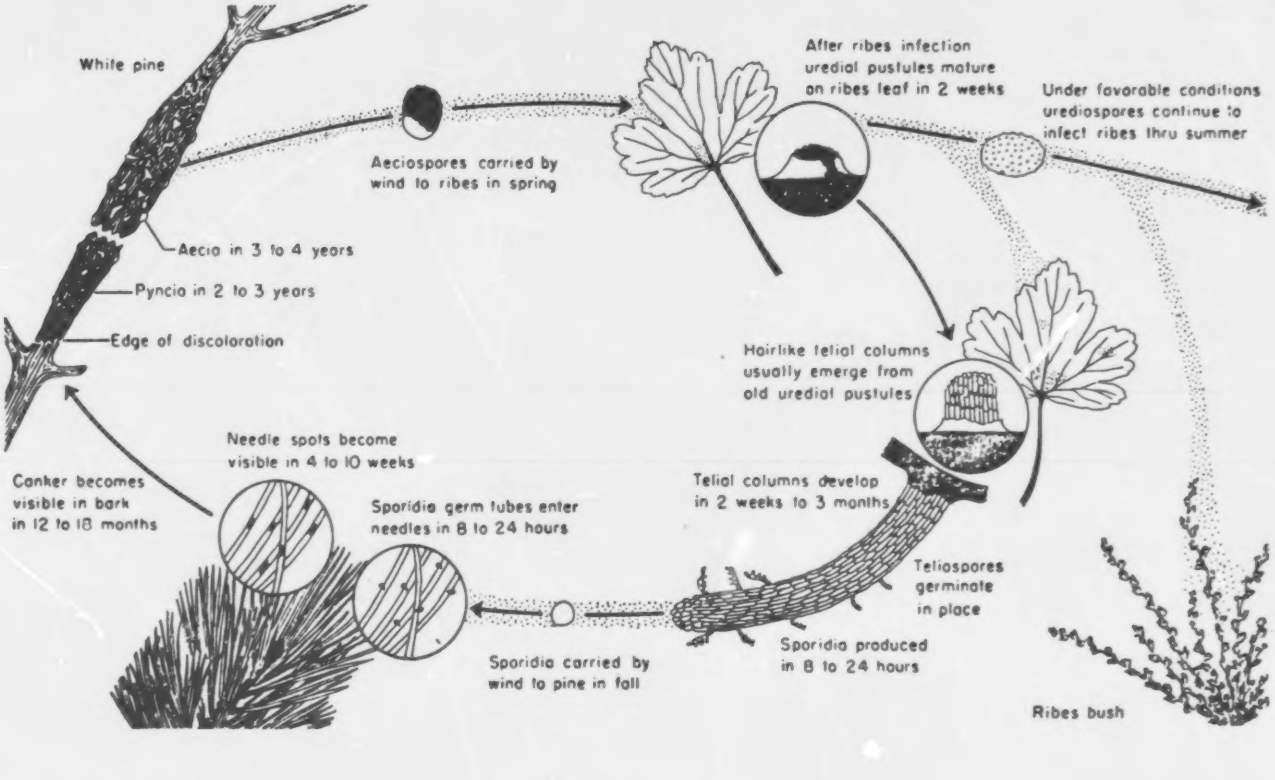
Symptoms

Numerous pale yellow blisters (aecia) as large as 3 mm (1/4 inch) across break through the infected bark in mid-April to mid-May a year or more after the bark first becomes infected. These blisters rupture and release great numbers of dry, yellow-orange spores. The bark ruptured by blister production dies within a few weeks and presents a greatly roughened appearance as it dries. Twigs, branches and trunks girdled by the killed bark die back to the site of infection, which is called a canker.

On the lower surfaces of living leaves of currants and gooseberries tiny orange pimple-like pustules (uredinia) produce yellow-orange rust spores throughout the summer. These spores cause repeated new infections on the Ribes leaves only until late summer, when another spore-bearing structure of the rust fungus appears on the Ribes leaves. This structure (telium) is a short yellow-brown hair-like filament. Large numbers of these filaments can give the lower leaf surface a fuzzy brown appearance. Spores (called sporidia) from these structures infect the pines only.

Disease Cycle

During moist weather in August and September, spores from Ribes leaves infect pine needles. The rust fungus slowly grows down the needle and into


White pine
Aeciospores carried by wind to ribes in spring
After ribes infection uredial pustules mature on ribes leaf in 2 weeks
Under favorable conditions urediospores continue to infect ribes thru summer
Aecia in 3 to 4 years
Pyncia in 2 to 3 years
Edge of discoloration
Hairlike telial columns usually emerge from old uredial pustules
Needle spots become visible in 4 to 10 weeks
Canker becomes visible in bark in 12 to 18 months
Sporidia germ tubes enter needles in 8 to 24 hours
Telial columns develop in 2 weeks to 3 months
Teliospores germinate in place
Sporidia carried by wind to pine in fall
Sporidia produced in 8 to 24 hours
Ribes bush

the twig. Blisters first rupture the bark in April-May of the second or third growing season after a pine tree becomes infected. The spores from these blisters cause new infections on the growing leaves of *Ribes* plants but are not capable of causing infections on pines (See disease cycle diagram). This alternation of host plants is essential for the perpetuation of the fungus; it cannot complete its life cycle on the pine or the *Ribes* alone. The infected pine tree provides a place where the rust fungus may safely overwinter, for it cannot survive in the *Ribes* leaves or outside a living host plant.

Control Strategy

Grow susceptible pines in locations where rust hazard is low. Reduce the hazard, where economically feasible, by eradicating the alternate host (*Ribes*). Reduce the incidence of trunk infections by pruning off low branches, whether or not the branches are infected.

Summary - Some Diseases of Forest Crops

Name of Disease	Type of Injury	Plant Attacked	Plant Parts Attacked	Infectious or Damaging Agent	Diagnosis	Control Measures
Annosus root rot	Dead trees, windthrow, poor growth	Pines, other conifers	Roots	Fungus	Conks on stumps or base of dead tree, decayed roots	Treat stump tops to prevent infection; convert badly damaged stand to hardwoods.
Armillaria root rot	Dead trees, poor growth	Most trees	Roots	Fungus	Fungus fans between bark and wood, rhizomorphs, decayed roots	Prevent defoliation or other weakening occurrences; pull stumps; soil fumigation.
Beech bark disease	Trunk cankers, dead and dying trees	Beech	Trunk	Scale insect and fungus	White wooly patches on trunk, bleeding spots, red pimple-like fruit bodies	None available; harvest beech before infection occurs.
Damping-off	Death of germinating seeds or young seedlings	All kinds	Germinating seed or stem at soil line	Fungus	Seedlings, fail to "come up", or die after emerging	Soil fumigation, fungicidal seed treatment or soil drench; management of soil pH, temperature, water content.
Fusarium root rot	Stunting, death of seedlings in 1st or 2nd growing season	Confiers	Roots	Fungus	Yellowing, stunting, wilting of seedlings	Soil fumigation, fertility management, nursery hygiene.
Heart rot	Decay of wood in trunk	All trees	Trunk	Fungi	Conks, openings into trunk, poorly healing branch stubs, old wound scars	Avoid wounding trees, prune early so as to minimize size of necessary wounds.

Summary - Some Diseases of Forest Crops (Cont'd.)

Name of Disease	Type of Injury	Plant Attacked	Plant Parts Attacked	Infectious or Damaging Agent	Diagnosis	Control Measures
Hypoxylon canker	Girdling canker on trunk	Aspens	Branches, trunk	Fungus	Discolored or blackened area of bark, dead top	None available
Lophodermium needlecast of pine	Killing and loss of needles	Pines	Needles (can defoliate and kill tree)	Fungus	Dead or discolored needles	Destroy severely diseased plants; spray monthly during summer; plant resistant varieties.
Nectria canker	Target canker on trunk	Maples, birches other hardwoods	Trunk	Fungus	Canker showing bare wood with concentric ridges around edge	Kill or cut infected trees during stand improvement work
Oak wilt	Wilting and death of tree	Oaks	Whole tree, or branch by branch in white oaks	Fungus	Bronzing and casting of leaves, death of tree, streaks in outer sapwood	Not necessary in forests; avoid wounding landscape trees in spring
Pine-Pine gall rust (Western gall rust)	Dead or deformed twigs, galls on stems	2- and 3-needle pines	Stems, twigs, trunk	Fungus	Dead or deformed twigs or galls on stems	Cull infected seedlings; cut heavily infected trees in plantation; destroy infected trees near plantation site.
Rhabdocline needlecast of Douglas-fir	Dead or spotted needles; loss of needles	Douglas-fir	Needles (can defoliate and kill tree)	Fungus	Dead or spotted needles, green at base until premature casting	Rogue out diseased plants or trees (if in a plantation); plant on slopes; control weeds.

Summary - Some Diseases of Forest Crops (Cont'd.)

Name of Disease	Type of Injury	Plant Attacked	Plant Parts Attacked	Infectious or Damaging Agent	Diagnosis	Control Measures
Scleroderris canker	Dead branches, trees in plantations	2-needle pines	Twigs, branches, trunks	Fungus	Orange-brown needle bases on killed twigs in spring, dead branches in summer, cankers with yellow-green wood beneath	Clean planting stock, fungicidal sprays in nursery, no new plantations or red, Scots, or jack pine near known infections.
White pine blister rust	Death of tree	5-needle pines	Branches, trunk	Fungus	Blisters on bark in spring, rough cankers at other times, dead branch or top	Prune off low branches, plant where rust hazard is low, eradicate *Ribes*.

VIII. MAJOR FOREST PEST MAMMALS AND BIRDS
RECOGNITION, BRIEF BIOLOGY, CONTROL STRATEGY

Although they usually are considered to be desirable inhabitants of forest environments, some mammals and birds may seriously damage forest crops. Such damage often is overlooked or tolerated by landowners. Occasionally, however -- and particularly in forest nursery operations -- such damage may become economically significant and control measures are indicated. Conservation officers may issue permits to take wildlife whenever it becomes destructive to private property.

Deer

Deer feed mainly upon the buds and twigs of trees and shrubs. Resulting damage is easily distinguished from rabbit damage; deer have no upper front teeth, so must twist off the twigs, leaving ragged broken stubs. In contrast, the stubs left by rabbits look as though they had been formed by a single cut from a sharp knife. Deer browsing may kill or deform young trees through repeated browsing of twigs up to seven feet from ground level, plus additional heights depending upon snow depth. In large areas, such as forests, deer numbers must be reduced by harvesting sufficient animals; there are no repellents currently available which are economically suitable for use over wide areas. Small areas such as nurseries may be protected by deer repellent compounds sprayed upon the trees. The tops of nursery trees may be dipped in a thiram formulation to provide protection at the time of transplanting. Brush or spray applications may also be used; a more dilute solution may be used as a spray during the growing season. Compounds containing the ingredient thiram are also effective in repelling rabbits. This is most economically feasible for protection during months that nursery stock is dormant, or in Christmas tree plantations.

Rabbits

Cottontail rabbits are active year-round and feed upon the buds, twigs and bark of young trees in winter. The sharp, clean "slice" made when these animals clip off a terminal shoot looks as though it had been done with one stroke of a sharp knife.

Small areas of high-value trees such as nurseries may be fenced effectively against rabbits, using a tight chicken-wire fence of one-inch mesh. Commercial rabbit repellents may be sprayed or painted on young trees two feet higher than the snow is expected to drift. Frequent cutting of grass, weeds and brush in nursery areas and Christmas tree plantations helps to reduce the protective cover for rabbits. The tops of nursery trees may be dipped in a thiram formulation to provide protection at the time of transplanting. Brush or spray applications may be used; a more dilute solution may be used as a spray during the growing season. On larger areas, trapping may reduce rabbit numbers if several traps are used persistently. Box traps should be baited with apple or carrot. Where guns may be used safely, one of the most effective ways to reduce rabbit numbers is through shooting. A good rabbit hound will greatly increase hunting effectiveness.

Woodchucks

Woodchucks may occupy forest habitats, particularly woodland edges. They dig extensive burrows with two or three entrances, in which they hibernate during winter months. A mound of freshly dug soil at a burrow entrance, during spring months, identifies an actively used burrow. The bark of young trees in the vicinity of burrows may be severely damaged by chewing or clawing.

In April and May, woodchucks may be destroyed by fumigation of actively used burrows, with little danger to other valuable animals that sometimes occupy deserted "chuck" burrows. Special cartridges for gassing woodchuck dens are manufactured by the U. S. Fish and Wildlife Service and are sold through hardware and farm-supply stores. Avoid using them when fire hazards exist. Shooting and trapping are also effective. A skilled rifleman can control a local population of woodchucks within a few days. Number 1-1/2 or number 2 traps may be set at burrow entrances and concealed with a few leaves; they should be well-secured to prevent their being dragged into the burrow. Repeated control is necessary with all methods, as vacant burrows are quickly occupied by woodchucks from adjoining areas.

Field Mice

Field mice are among our most prolific and numerous mammals and are found wherever there is grass to feed upon. They construct networks of surface runways through the vegetation in summer and dig 2-inch-wide tunnels through snow in winter. During winters, particularly, they may gnaw bark from young trees. Usually this damage is not extensive enough in forest situations to warrant control. When such damage is extensive, mouse populations are usually very high. High mouse populations one year are usually followed by very low populations for the next several years, allowing forest regeneration to proceed without serious delay.

Zinc-phosphide treated grain baits are highly effective in reducing populations of these mice, but generally are economically feasible only on small areas which support high value trees, such as nurseries and Christmas tree plantations.

Tree seeds may be treated with thiram to protect them from damage by mice. This compound acts as a taste repellent.

Birds

Tree seeds may be treated with thiram to protect them from damage by birds through its action as a taste repellent.

Dormant terminal buds of small specimen trees may be protected against Pine Grosbeaks by small plastic sacks. Where serious damage is extensive, U. S. Game Management Agents may issue permits to kill migratory birds. Generally, shooting in the area where these bird flocks are feeding will move them to another feeding site.

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R. F. Pendleton, Cornell University	Chemicals-Pesticides
E. G. Terrell, Bureau of Forest Insect & Disease Control, N.Y.S. Department of Environmental Conservation	Seed Production, Tree Nurseries

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POISONING HAZARD TO HONEY BEES OF INSECTICIDES AND MITICIDES ON BLOOMING CROPS

Use Rating	Residual Toxicity	Material
Hazardous to honey bees at any time	High, 1 day to 2 weeks	arsenicals, Azodrin, Baygon, Bidrin, carbaryl (Sevin), carbofuran (Furadan), chlorpyrifos (Dursban), Dasanit, dichlorvos (Vapona), dimethoate (Cygon), dinoseb, endothall, EPN, fenthion (Baytex), Guthion, heptachlor, Imidan, lindane and benzene hexachloride, malathion D, malathion ULV, Matacil, Methyl Parathion, Methyl Trithion, naled (Dibrom) D, parathion, Phosdrin, phosphamidon.
Not hazardous if applied in either evening or early morning when honey bees are not foraging, except during periods of high temperature in these times	Moderate, 3 hours to 1 day	Abate, carbophenothion (Trithion), Carzol, chlordane, demeton (Systox), dioxathion (Delnav), Di-Syston EC, endosulfan (Thiodan), endrin, ethion, heptachlor G, malathion EC, methomyl (Lannate SP), methoxychlor, Meta-Systox-R, Morocide, naled (Dibrom) EC, VC-13 Nemacide, Orthene, Perthane, phorate (Thimet) EC, G, Phostex, Phosvel, TEPP, Thanite, Torak, toxaphene, trichlorfon (Dylox), Zolone.
Not hazardous to bees at any time	Low, 1 hour to 1 day	Acaraben (chlorobenzilate), Acaralate (chloropropylate), allethrin, Baygon G, carbaryl (Sevin) G, carbofuran Furadan) G, Dasanit G, Dikar, Di-Syston G, Galecron and Fundal SP, Karathane, Kelthane, lime-sulfur, malathion G, Morestan, oil sprays (Superior), propargite (Omite), Pentac, Plictran, pyrethrum, rotenone, sulfur, Temik G, tetradifon (Tedion). Most herbicides and fungicides.

Abbreviations: EC - emulsifiable concentrate; D - dust; ULV - ultra low volume; WP - wettable powder;
G - granular; SP - soluble powder